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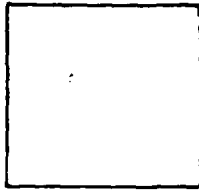
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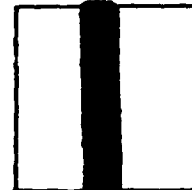
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DOT/FAA Human Factors Workshop on  
Aviation Transcript - Volume II  
DOCUMENT IDENTIFICATION

24-25 Nov 80

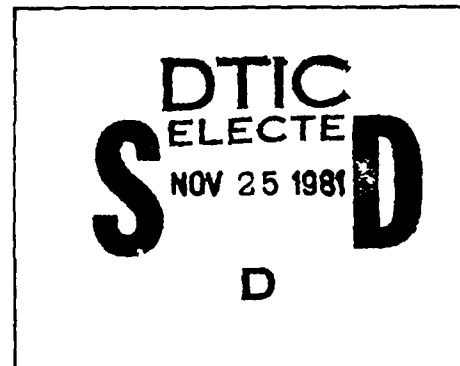
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**DOT/FAA  
HUMAN FACTORS WORKSHOP  
ON AVIATION  
TRANSCRIPT - VOLUME II**

AD A107803



Sponsored by the  
U.S. DEPARTMENT OF TRANSPORTATION  
Federal Aviation Administration



**November 24 & 25, 1980**

Presented at the  
Transportation Systems Center  
Kendall Square  
Cambridge, Massachusetts

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DOT/FAA  
HUMAN FACTORS WORKSHOP  
ON AVIATION

SESSIONS 3 AND 4

Sponsored by the  
U.S. DEPARTMENT OF TRANSPORTATION  
FEDERAL AVIATION ADMINISTRATION

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Cambridge, Massachusetts  
November 25, 1980

81-71



## FOREWORD

This document is a verbatim transcript of the proceedings of the DOT/FAA Human Factors Workshop on Aviation held at the Transportation Systems Center in Cambridge, Massachusetts on November 24-25, 1980. No editorial corrections have been made. Additional workshops/symposiums are scheduled to address human factors safety issues. On January 16, the Second FAA Commuter Airline Symposium will be devoted to human factors. In addition, another workshop is planned to be held at the Transportation Systems Center during March 1981. Proceedings will remain open until 60 days after the March 1981 workshop and then will be published in their entirety.

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## PROCEEDINGS

MR. ANDERSEN: Good morning everybody. I was talking to Walt Luffsey this morning and he asked me to clarify or amplify the point he made in his opening remarks yesterday. As you know, what we are trying to do in this workshop is to get as many inputs from you people as we can possibly get. What Walt would like you to think about is if there is something on your mind or something you want to bring up in front of this group or something you want to get into the docket, just feel free during the remarks session to get up and do just that. The panel may not be able to respond, but somebody else in the audience may want to. So think about that today and this afternoon when we have discussions; if there is anything that you want to get out for discussion, please feel free to do that. Is that about it, Walt? OK.

This morning session is on Aircraft Manufacturing Industry Programs, and we have C. Ronald Lowry, as the moderator. Ron is the Vice President of Research and Technology for Aerospace Industries Association. Ron.

C. RONALD LOWRY: Thank you, Jim. Before we get into the panel discussion, let me briefly set the stage by providing you with some overall aerospace industry viewpoints. First, AIA fully supports the concept of FAA's five-year program because human error is still a major contributor to aviation accidents. We recognize that improvement must be sought and that the human factor techniques must be emphasized throughout the system.

Second, we agree with Langhorne Bond's statement yesterday that this initial workshop should devote itself to identifying questions to be answered and not to solutions.

Third, we also agree very much, as a matter of fact, with the ALPA comments yesterday that the complexity, breadth and significance of this subject literally demand that a system approach be used. Since the aerospace industry believes in a system's approach, that leads to my final general point which is this; success of this five-year program to improve the safety of air transportation by reducing the incidents and the consequences of human error will depend upon and indeed require management of the highest order, strong centralized system management. Saying it another way, the development of specific program requirements in subsequent stages of planning,

the allocating of resources, and the program conduct with all be critical. We look forward to working with FAA on the follow-on working sessions whereby such program elements can be cooperatively developed.

Also we would caution that if the new program is to insure meaningful results, FAA should not fractionate the program into too many small, single-subject items. Nor should FAA use the program to develop an expanded in-house capability, in our view. Nor should research money be apportioned among universities, government labs and industry in an unbalanced way. Nor do we believe that the oversight committee should exclude participation or input from such key groups as the airlines, services, NASA and manufacturers if we are to truly solve the real world problems. Well, enough of our general views for now. Let's turn to the panel presentations.

With me today are some of the genuine experts of the field of human factors practice. Each company represented will review how they apply human factors in the context of their experience, design philosophy and current activity.

You have their full name, rank and serial number in the program. So to save time and get into it, I will introduce them only by name in order of presentation. From Boeing on your right, Delmar Fadden will make a presentation, and Dr. Frank Ruggiero will assist Delmar in the Q & A. Next, the Lockheed team, Dick Heimbold will make the presentation, and Ralph Cokely will joint him in Q & A. From McDonnell Douglas, a two-part presentation. Dr. Dick Gabriel will lead off, and George Jansen will fly the second section.

As was done yesterday, we will ask you to hold your questions until the end at which time we will be glad to respond to any and all. Del, all yours.

DELMAR M. FADDEN

We're delighted to have this opportunity to talk about how we apply human factors in the design process. We believe forums such as this are useful in developing a perspective within the community so we can all address those important issues.

Our objective here is to describe how we develop an understanding of the pilot's needs and the design process that we use that enables us to meet those needs. That's a big order.

The way we decided to break it down, we'll talk a bit of how we develop the understanding, where the information comes from, some generalities of the design process and then try to describe it more specifically with three examples dealing with specifics of two pieces of equipment and then how it's applied across the flight deck in general, and summarize.

The most important part is how we develop an understanding of what the flight deck problems are. They come from five major sources and those sources are a continuing process. The pilot contact we seek, we develop through a number of different sources.

Our pilots talk to the pilots that fly our airplanes. Our pilots talk to the representatives of the unions that operate the airplanes and to the management of the airlines that operate our airplanes. And that is on a continuous basis. It's not just when we are starting a new program.

Our engineers talk with the pilots that fly. We go out and fly with the airlines as observers on their aircraft. We talk to them in plant. We talk to them in forums such as this. We participate in industry operations oriented committees where we get to talk one-on-one.

The one-on-one experience is crucial to developing an understanding of the nature of the real problem.

When we're involved in a specific program such as we are now with the 757 and the 767, this contact is more complete, more regular and involves more people; for example, our major customers on our two new programs have had five major meetings with us from the time the initial orders were placed up through the present, and we are now just over half way through the program.

Two of those meetings involved line pilots from each of the airlines. In some cases, all five of the meetings involved line pilots, not just management pilots. That contact involves pilots on our side and engineers so we can sit down and discuss the issue directly across the table. Whenever possible, it includes mockups or hardware or simulation as well.

Pilots from Boeing fly as crew members under the contract with a number of airlines around the world supplementing the airline pilots for various reasons. And in this opportunity, we get to fly in the seat, in the environment using the procedures that the airline uses so we see how its done in

practice. Often that is with a mixed crew, one Boeing man going and two airline men or one other airline man, so we see how the airline operates and how the people within the airline operate. It gives us a broader perspective on how the operations are worldwide.

Airline operating experience is another valuable source. We obtain the service records on all of our airplanes so we know that the problems are with them, what's been reported, what's failed, what's been inoperative, what hasn't worked. We also get data from our vendors on what their contact with the customer indicates are problem areas. Beyond that we run a series of symposiums on a continuing basis for our product lines. Many of those involve operations and concerns and bring together people from the airlines from the operations of our aircraft who have concerns in a particular area. Here we get the benefit of airline-to-airline discussion, identifying common problems, different ways of solving the problems that the airlines have developed.

In the accident and incident analysis area, we, of course, obtain the formally published data about accidents and incidents, and we try to go beyond that for our own airplanes. When there is an accident or incident, we have both the pilot and the engineering representation on the team that investigates the accident. We try to go beyond what the published cause is to see what the influence might be on future designs or on that design. We look for trends and patterns across the industry.

And we collect data from a worldwide data source. That data is made available to our designers directly and to our engineering teams in the research department with the company to look at possible solutions both to be applied to our current product line and the future products.

Our training program is very large. We train pilots from around the world. Many airlines do all of their training with us, others train only their initial cadre with us. In any case, we deal directly with the training departments of virtually all the airlines in establishing the initial training. It's not to say we set it up but we work with them in setting it up, and we understand how they do it and we understand how we'll do it. That's a very useful source because we find there how to go about doing the training, what really works and what really doesn't and what types of problems pilots encounter when they transition in doing their airplane.

The designer process differs in every specific application, but it does have some common threads. The common threads are analysis, simulations or mockups, and then flight test.

The analysis phase starts when we have a paper design, or early in the paper phase, and it allows us to look at a wide range of possible solutions. It establishes the basis for the initial hardware implementations.

In the mockup, lab test or simulation phase, we can validate the concept of function and quantify the results. And then in flight tests, confirm operational suitability and examine those factors that aren't identifiable in the analysis or simulation phase. The process is iterative, gone through several times in some applications. All phases of it are important. No one phase works by itself.

I'm going to describe two examples. The first one we'll talk about is the crew seats. We have a lot of concerns expressed to us through the sources. I describe pilot sources saying that our seats are cramped, they're too hard, they don't support the body properly, they're too small, too much pressure on the legs. They're uncomfortable to sit in, they get warm, sticky, etc., - lots and lots of descriptive terms. What it comes down to is the seats are often uncomfortable.

We latched into a seat development program to see what we could do about it, to see if we could solve it because we believe the pilot should be comfortable in the environment he is operating. He will do a better job if he is comfortable.

The analysis phase identified several possible areas of improvement. We found that the range of body dimensions for the pilot population that we are using now are somewhat different than what was used for the original seat design and indeed there are some discrepancies.

There are several new materials that could be applied for the seat design problems. And there are the possibilities of applying contouring, different levels of contouring to the seat to provide better support. We established a range of possibilities in each of these three areas and then went out to the airline operations department to talk with them about the possible areas. Have they had experience? How did they see our possible solutions as fitting their situation? This was both our new airplane customers



and a number of the current customers. From that we established several candidates' solutions to take into simulation.

We build a simulation system to look at the seat both subjectively and objectively. We developed questionnaires and applied the questionnaires in a very structured form. We also developed an objective measure. We put the seat, a variety of seats on a platform with strain gauges and measured the CG shift as the person moved in the seat. We called it the squirm test, and we found that it was a very good correlation with the subjective measure, a very sensitive measure. From this test, we tested six different seats over a period with six different pilots, each pilot operating in the seat two hours during a variety of jobs. Out of this, we found that the sheepskin covering shown here reduced the squirm in the seat by about 55 percent, and it ranked first in the pilot preference. We also found that an adjustable lumbar support, particularly a mechanically adjustable one, was ranked very high and gave consistent results subjectively and objectively. Out of this, we quantified the results and we were able to select which features we wanted to take into flight tests and examine further.

In the flight test, we dealt with six different airlines putting the seat with the sheepskin covering on it in line service and operating it for a period of time. The line experience did confirm that the pilots felt the seat was more comfortable. We had excellent results from that, and it demonstrated the service suitability of the covering material. At the same time, we put the covering material into an accelerated lab test to evaluate any hazards from the seat material itself and to demonstrate suitability, serviceability over an extended period of time. As a result of all of this testing, the sheepskin cover is basic on all of our current airplanes for any new purchase, and it's available as a retrofit on any of our existing airplanes. And it's basic to the new ones. Similarly, the lumbar support is on all the new seats and the new seats reflect the larger dimensions.

Now the next example deals with a different issue, the very complex issue of the pilot's role in an aviation and guidance task. Here the development task has taken many steps, has taken a much longer period of time. Several cycles in the analysis simulation and flight test were required to establish the suitability of making this change.

Pilots do an excellent job of flying airplanes equipped with instruments such as those on this 747 and yet there are some concerns. The information is spread out on a series of different instruments. VOR instrument on the RMI providing two pointers. The DME above it is in digital form. The HSI directly under the ADI provides deviation from path and course angle as well as heading. And then the radar indicator on the far right showing the plan position relative to weather information. All are used by the pilot to build a mental picture of the conditions or a theory of the situation. The decisions tend to follow from this mental imagery.

We believe if we could create a picture for the pilot, we could lower the cognitive workload associated with collecting and integrating the information without affecting the decision making, keeping the pilot in the decision making loop. The new displays for the 757 and 767 do just that.

This is a picture of the prototype equipment or what we call our blue label prototype. It's the initial prototype for the 757 and 767, primary flight instruments.

Let me just describe what's on the instrument. At the apex of the triangle at the bottom is the present position of the airplane. The straight line leading to the top of the display is the current track line. The white line diagonally across the display is the planned path line with four pointer stars indicating the way points. The next way point in the plan is designated by different color than the further way points down the path.

The two VORTAC symbols, one marked ABC and the other XYZ are the VORTAC that are being tuned by the flight management system. The arrow and the number in the lower left-hand corner is the wind direction relative to the airplane and the speed.

The two scales, the scale at the bottom represents the linear path deviation laterally, and the scale on the right indicates the vertical path deviation assuming that the flight plan is three dimensional.

And the numerical data at the top gives the data the pilot needs to communicate with air traffic control concerning distance, angles, and time. And then the portion of the compass rose provides a reference into the angle coordinate system. Right next to this instrument is an RMI with a full compass rose so the pilot does have a full compass rose information. Underneath

the map information is the radar information in the same format and at the same scale. The pilot has control of the range of both the radar and the map with a single switch.

The radar data electronically follows the track angle of the airplane, and it is updated as the airplane turns between sweeps so that the radar data appears to move smoothly on the map.

There is a number of relationships available on this type of a display that are not available to the pilot from conventional instruments without him taking specific effort to think about it. The relationship between weather and way points, for example, is not at all clear from the conventional instrumentation where here it is perfectly clear. On this type of a display, we can provide predictive information about what the current policy, what current strategy he is using. For instance, just ahead of the airplane are three-lines curved slightly to the left. That predicts the path the airplane will follow if the pilot maintains the current ground speed and turn rate over the next 30, 60 and 90 seconds.

It all sounds great, but how do we know it's going to work? Well, it's based on work that has been going on throughout the industry for a long, long time. The original automated chart displays were developed in the '50's, '60's. They have been flown in Europe and in the United States on a variety of airplanes. Pilots have experience with them. They identified what they liked, what they didn't like. There have been a variety of experimental systems developed throughout the United States and in Europe. Again those have been tested, many through simulation and into flight test and each time what worked and what didn't work was identified. Very frequently, it was written up or made available so we can all benefit from it.

The military has done a good deal of work with chart displays in one form or another. They have used film chart displays and film CRT chart displays on several of their aircraft. And there's good data from that.

Analysis of all of this leads us to believe that CRT solution was the better one given the state of technology at the moment and that the instrument should be applied as a primary flight instrument so that it's in front of the pilot all the time and not treated as a secondary instrument.

Now the work that we have been directly involved in started back in the late 1960's as part of the going SST, the picture in the upper left-hand corners of that particular slide is of our SST developmental simulator, which many of you may have flown. It was available in Seattle in '69 and early '70. A large number of pilots flew in that. And the data we obtained from it gave us our first thorough understanding of what it takes to do a CRT display.

I think the key lesson from that one is that the display has to be kept simple. It has to have low information density if it's going to be used effectively. And the pilot needs control of the information density on the screen. Every time we try to do it automatically for him anticipating his needs, we found we did it wrong; and the best solution was to let the pilot have control of the data on the screen. We give him the bare minimum and let him add what he wants. That program developed in the early '70's into the SST follow-on Phase 2 FAA and DOT where we could confirm the concept in flight test. We put the equipment that had been developed for the SST into the front of the 737 and flew it for FAA. It confirmed primarily the engineering feasibility of doing the job.

The flight test was fairly short, but it did confirm that the concepts themselves were useable. Further testing was required and NASA through their TCV program has been doing the majority of that testing.

The TCV shown on the center and on the lower right has given us the opportunity to extend our understanding in the real operating environment. It's a unique and extremely valuable tool. It's exposed the concept to many more pilots and into an unbiased environment not directly involving Boeing all the time, which helps expose what the problem areas are.

We have identified many features in the display, many details about how the display can and should be used through that program.

Also in the mid '70's, we developed for the Air Force the YC 14 program. While it didn't have a map display, it did have a CRT attitude director on it, and it was being operated in a cockpit that had a great deal of light in it. We learned a great deal of the image quality that was necessary on a CRT through that program.

The results of all of this testing give us quantification of the concept. I can't stress how important that is. Until a concept gets beyond philosophy

and into real numbers, it isn't something that can apply to an airplane. We have, in fact, quantified what's needed in terms of brightness, in terms of symbol shapes, in terms of sizes on the screen, colors, both the hue and amplification of the color, a great deal about image stability. We find that we do have to be considerably better than home television but exactly how much? It's important to know because it's costly to do, and similarly, it's costly to the pilot if we make a mistake. In the operational context, we confirm the information content, both by what the pilot thinks he needs and what he performs well with. Both are important. We confirm the dynamic characteristics. There is nothing as important to the pilot as the dynamic characteristics of the piece of information on the screen once it's there.

The dynamic characteristics can make or break a very simple concept. We have found that we have to go into flight test to confirm that simulation results or they indicate the basic concepts are often correct but don't give us enough detail about the dynamic characteristics.

Finally, all of this testing has given us assurance that we have got a display that's compatible with pilot expectations. These two examples are dealt with individual features within a flight deck.

The next step is to put the whole flight deck together and that addresses many additional concerns beyond those associated with an individual piece of equipment. The pilots have told us, and as you've heard yesterday, we absolutely believe that there are concerns in the area of traffic control, weather, congestion, schedule pressure or economic climate around the airlines, fatigue and operational fail systems, to name just a few. These all must be addressed in the design of any complete flight deck. This same process that we've used before, analysis simulation and flight test, we believe is the key to solving that problem through the design.

The analysis again on the paper phase particularly gives us a chance to look at the various concepts and then to focus our efforts for the simulation phase.

The simulation phase improves our confidence in the planned operations and provides some data that is useful in the final design and then the flight test confirms the suitability in real conditions and is the final proof.

Now I would like to go through each of these three as it's applied to the workload process specifically at Boeing. The workload analysis starts early in the program and continues through the life of the program. It starts with an understanding of the operating environment that the airplane is going to be operated in, both in concept and in detail specifics. We visit the facilities along our typical scenario routes, and we fly airplanes from various carriers flying over those same routes, so we see the process from both ends. And we talk to both the managers and the people on the radar scopes and the people flying the airplanes about the route, how it's really done. From that, we can develop a series of flight scenarios that describe the mission profile that the airplane is to follow. While the design project is developing the functional design, the initial functioning design and with ourselves and the training department of Boeing, we develop the CPS's initially, internally and then with airline assistance for the operating procedures on the airplane. That put in the context of flight deck geometry allows us to innumerate the detailed actions the crew has to go through to complete each step of the scenario. This has been put on a time line, and we go through computer processing. Out of the processing, we get a series of comparative workload measures. There is not a single one that we use. There is a whole series and the series treat a variety of subjects. Can controls be reached? Can they be seen? What's the viewing angle to the controls, mundane but important points. More specifically, what's the time required in the visual air? What's the time required for motor tasks, for cognitive tasks, for verbal and auditory tasks and how do they compare with tasks in a similar airplane or reference airplane flying over the same route but with it's airplane system and it's performance capability?

What's the instrument dwell time? What's the transit time between instruments for each crew member and for the group as a whole? What's the panel efficiency of our various instrument panels, control panels compared to our own designs and the designs of other manufacturers? All of this is done on a comparative basis so we avoid the problem of an absolute reference.

The analysis of this is done by a series of people skilled in a variety of areas, both psychology and engineering, human factors and pilot. Out of that analysis, we identified changes that are required in operational procedures in the functional design of a component or a subsystem or the arrangement

of components or the need for additional testing to understand further what's happening between the pilot and the machine.

Analysis is a continuing process. It starts early and it goes throughout the program, but it's just one of the ways that we develop an understanding of what the final workload would be like.

The next phase, a flight simulation which we get into two steps, initial step with individual pieces of equipment very early and then a more complete step later in the program when a full set of airplane equipment is available. In this phase where we have the full flight deck geometry, got the correct relationships between the instruments and the people on the flight deck and typical instruments, controls and displays although not exactly what will be in the final airplane. And like a training simulator, we need to operate with predicted airplane, system and operating equipment, operating environment characteristics.

The prediction here is a limitation on this type of analysis. It is the best prediction that we can use. We are a conservative company and so the prediction is particularly conservative. Out of this, we do pilot and flight operations testing specifically aimed at the control task, flying the airplane task in the native environment, flying over scenarios that we've established for the analysis and conducting normal procedures, abnormal and emergency procedures, the whole range of them. It's a valuable test facility. It has some inherent limitations but there is much useful data that comes out of it. It does improve our assurance as we move into the flight test phase that we will be successful.

In the flight test phase, all of the aircraft characteristics are present, secondary ones that we didn't expect, the whole range. We're operating in the actual operating environment and all of the factors affecting crew members performance and behavior are realistic. A stress in flight is different than the stress on the ground. All types of operations are conducted, normal as well as a series of failures and various combinations of failures. That program for example, for the 767 the flight test period will stretch over ten months. It involves virtually all phases of our engineering staff as well as our pilots.

In summary then, we develop our understanding of the pilot's needs primarily from the pilots themselves and very much from one-on-one contact around the world continuing over a long period of time and from the line operating experience that we obtain both directly and indirectly. And we believe we have a design process that enables us to meet those needs using the fundamental principals of analysis simulation and flight test.

Thank you.

MR. LOWRY: Thank you, Delmar. And now let's turn to Lockheed and Dick Heimbold.

RICHARD HEIMBOLD

Thank you Ron. It's a pleasure for us to be here at the Human Factors Workshop for Aviation. And as we all know listening to the last couple of days presentations, this field is an enormous one.

We at Lockheed feel that there are some areas in which we can make a contribution. What I would like to do today is describe a little bit of the human factor related test that we have done in the past and talk a little bit about what we are doing today; and through that process, get across a point of how we approach a human factor related problem.

At the end of my slides, I would like to make a few thoughts which have to do with what this workshop may produce in the future. First I would like to say a bit about the L-1011 flight station design. This was a team effort. Human factors were grouped and this group for this particular job was lead by Les Susser, who is in the audience today. I mention that in case there are detailed questions about his area of expertise. But his team works closely with engineers, they work closely with Lockheed pilots and they work very closely with airline pilots with what we think is a very efficient cockpit design.

The design was a three crew member design. It was designed for quietness by the use of curved windshields. We discussed that on wind noise. That has an important impact on fatigue. The visibility was worked on intensely and as a result, the crew members have a very wide field of vision looking forward through the cockpit and also out to the sides.

Instrument panel layout was made to a group in such a way that scan patterns were reduced and that they were in the most convenient places.



Control column was designed with the low profile so that the crew member's views were not impeded. A look at the co-pilot station gives some idea of the visibility and another interesting feature of the design. There was great emphasis placed on what is called delethalization. If you notice around the co-pilots head, there are no toggle switches that could strike in the case that he jumps up quickly or suddenly or for some reason his head comes in contact with the overhead or the side structure.

I might mention that there are 38 square feet of glass in the L-1011 cockpit. There's great use made of push buttons in the L-1011 as opposed to toggle switches, and this push button technology which included integral illumination was a further way of improving scan in the use of operation.

This is a forward view of the cockpit and a feature here that I didn't mention is visible in this view with the pilot sitting in the correct position which is determined by an eye locator on the central column. The view through the front windshield presents him with horizontal and vertical cues.

The autopilot panel is shown below the glare shield. This is a panel which makes wide use again of push buttons. It's easier to reach, easier to understand. This particular airplane incidently is equipped with full flight management system.

The CDU panels are in the center. There are two of them right next to the throttles; and with this equipment, it's possible to fly the airplane completely automatically. Following rotation which is done manually, the pilot can climb with a number of different climb strategies including different NDG rates to suit the particular operator. He can cruise in an efficient way. The FMS will advise him when to make a step climb and then at the end of this cruise portion, it will descend again automatically putting the plane at a point in the airport which is exactly where he wants to be at the end of descent. The navigation, of course, again is all completely automatic. He can fly airways, RNAF, use the iron platform, whatever the mission requires.

Another interesting feature of this aircraft is a map display. It's behind the throttles. This is a black and white tube characteristics of 1970's technology. That's been in commerical service for about three years now.

And that presents to the pilot way points, VORTAC, things of that nature and allows him to see where he's proceeding over the earth.

This is a flight engineer's panel and in this application there was kind of a pioneering use again made of push button switches. And the use of push button switches allow some very interesting flow path models to be drawn on the panel. This panel incidently is quite in the current trend of dark panel, dark cockpits. When a button is depressed, a flow path illuminates through the button to show that that channel whether it's electrically powered hydraulics, whatever, is opened. For the most part, unless there is an image, the panel other than a flow path is dark. There are some panels from push buttons besides their compatibility for multiple messages through illumination; for example, if one falls against the cockpit panel in flight, pushes on it with his hands, none of the buttons are activated. Conversely, with toggle switches, he might turn on or off a bunch of switches by so doing.

There is a number of test facilities used for optimizing the human interfaces on the L-1011. This is one of the funnier looking ones, so I have shown it here today. Besides this mockup which is a lighting mockup, there is very extensive use made of flight simulators, different types of mockups for geometric and anthropometric measurements. In this particular lighting mockup, it's a device where the cockpit at different angles and at different conditions of sunlight can be evaluated and a great deal of work was done here to optimize the color schemes at different situations in amber light.

I might mention, too, that in the development of the cockpit, the seat design was very important. And the resulted seat has variable density of foam in it. Experiments were run with subjects sitting in the seats for many hours on end. The seat was designed a little bigger than necessary. It goes from, I believe, 2 percent to 97 percent of the population, which turned out was fortuitous because a lot of our customers are oriental or people a bit shorter or from Northern Europe where they tend to be a bit on the large size.

The seat is fully adjustable. It's continuously adjustable so the pilot can locate his eyes at the perfect position by the eye locator. It has an adjustable lumbar support, adjustable thigh supports. Incidently, yesterday was mentioned that a lot of automation in cockpits is not known to the pilots, and they don't use all this sort of stuff. Here is a humble example of this

that Les Susser was telling me. He was in a jump seat of a 1011 not too long ago; the pilot complained of thigh fatigue. He hadn't realized that there were thigh supports that rotated up from the seat to support his legs and prevent that sort of fatigue situation.

Now besides the crew station, we feel that there are profound impacts on the human factor's aspects of an airplane based on other systems in a plane.

For the 1011 right now, we are developing a digital autopilot. It's quadvuplex redundant. This is a replacement for the quadvuplex analog autopilot, I should say, which has been in service for about the last ten years. This capability gives the aircraft a CAT III autoland in the U.S., CAT III B in the UK and of course, that has a great impact on the human factors test. It's a totally automated way of landing the aircraft, and it has proved to be immensely successful in service.

Flight management computer was something which evolved in 1971. An RNAV computer was installed in the 1011 and certified and over the years grew into a 3D type of computer. Now in '77, the 3D FMS was available, and this of course allows the airplane to be flown totally automatic and with a very fuel efficient flight profile.

There are features to make the pilot's workload less demanding, such as autotuning. This allows all the transmitting devices that will be overflown to be inserted part of flight and the flight then is almost hands off the rest of the way.

The direct lift control is something which is not thought of as a human factors type of issue; however, on the approach, there are direct lift control features which are a result of modulating the spoilers. Now this allows the airplane to track the flight path deviation movements vertically up and down without pitching and that has a great impact on the dispersion of the aircraft as it touches down on a runway. It affects the pilot's workload, passenger comfort and that sort of thing. So it turns out that that system application is something which has a human factor payoff.

The flying tail is another device. Again one doesn't think of this as something which is in the realm of human factors, but it does improve the safety of handling the airplanes, gives the pilot greater control effectiveness in a pitch access. It allows him to overcome, for an example, full down runway

pitch take-off. He can overcome that take-off and climb out. And the same thing applies for upset situations and that sort of thing.

Lastly, there's a new system which we are testing called the flight isolation data display system or FIDDS. This was flown for the first time last week. This particular system has an impact on maintenance human factors and let me explain a bit. The FIDDS system takes failures from two digital systems, the active control system and the automatic flight control system; and it records failures plus other relative data. Now by so doing, this allows the maintenance personnel to make very accurate maintenance decisions. And if in case one runs into intermittent failures, which do happen with electronic gear, it will record specifically when where it happened and other data which helps to trouble shoot that sort of thing. So the net result is it makes maintenance much more productive. It enhances the chance of replacing the right box the first time and that makes flight safer.

This is (referring to slide) the FIDDS panel in the flight engineer station. It has a number of capabilities. Here the operator is pushing the flight data recall button which would normally happen after a flight. And in this situation, data is putting out displays that's a first failure, the first one of its redundant sensors, that which has a flight number, the date of occurrence, airplane serial number and other data. We think that this sort of maintenance technology is really going to revolutionize the care and feeding of airplanes in the future because maintenance is expensive. It's a big task, and it's not always that productive. Many times boxes are removed from airplanes. They don't have to be taken out. Digital technology is helping to beat that problem.

Digital technology can detect its own failures in a much more accurate way; and when linked with this sort of system, we think that we're approaching the best of all worlds as far as digital maintenance goes.

A little more history. This is the S3A. It's an SAW airplane, shows a pilot station which has a very large CRT display in it. Now this airplane when designed really faced a formidable human factor problem. How do you take an airplane with the crew complement of 13 people, which the P3 has and do most of the work they do in a small carrier base plane? So by the application of increased automation and increased emphasis on human factors, the crew complement of the S3 was brought down to four people.

The co-pilot station has an even larger display in it and what made it possible to reduce the crew size so dramatically is that the displays here are very flexible; for example, on this display, the pilot can look at radar, he can look at forward looking infrared, he can look at electronic surveillance, and he can look at the mag gear, the magnetic anomaly and detector. With some of these things, the SAU for example, he can detect a submarine, it's location stored in the computer. The airplane has the capability of taking that way point for the submarine's location and flying to and -- automatically dropping the egg, and all-in-all has a very efficient use of the human resource on board.

That is a bit of the past. Now looking a little bit in the future. This is an artist's rendition of an advance cockpit design, and this is typical work which is being done by our sister company in Georgia, the Lockheed-Georgia Company; and incidently, there are a couple of gents from Georgia here today who are willing to talk about that if someone has an interest.

We envision that in the '90s there will be extensive use made of large panel displays which will be solid state in nature. And the Georgia Company has embarked on a very ambitious program to take a look at large displays.

Now for the time being, they'll be doing most of this looking with large CRT panels. Take a look at the left-hand panel. This is a very rough preliminary idea of what it might look like in the cruise's configuration, has an EIDI, beneath it, HSI. There's a checklist and a CBPI. These displays have great flexibility. They can be moved around at different flight segments; for example, different variations can be brought up. For example, now the pilots on the approach, he replaces the EADI with a half the space concept and his HSI accordingly is modified. If he chooses for a better flying path control, he can blow that up to full size of what might be an 18-inch screen.

Now this cockpit will be installed in 1983 in a moving base simulator. It will be a full mission simulator in that there is an air traffic control panel that an operator can sit at. He can talk to the airplane. He can simulate communications with the ground, that sort of thing.

Right now there is a display's lab which is shown in brown in the picture. That is in operation today, and the Georgia people are doing some research in that area.

Here's an example of a large panel CRT display. It's sectioned to show different types of information and different quadrants; and it's equipped with a touch panel. To actuate a switch, the operator simply puts his finger on the switch symbol and the display light comes on, and it says the switch has been actuated. And we think this sort of technology will typify flat panel applications in the '90's.

At Georgia, there is also a great deal of work being done in voice recognition and oral warnings, that sort of thing. This is another attempt to integrate the human being with the airplane and make use of another sense, sensory input and output.

This is an integrated flight engineer's station. This is subjective Lockheed-California Company Research. Now the existing flight engineer's station makes use of push button switches and that opens up very interesting possibilities in showing flow paths and networks. This display will maintain the thread of that approach to life except we think it will do it a bit better. This allows the flow paths to be illuminated any possible way; and in addition, there is great flexibility. Different panels can be moved around. They can be blown up, look-up data can be provided with it also. Right now our thinking is along the lines that there will be three large flat panel displays to embody this technology. And in case one fails, that leaves two left. The display's generator, of course, has to have similar levels of redundancy to accommodate it. In general we are in agreement with the dark panel approach to light. This display shows a failure of an electric generator. It's overheated and shown in red. And that has other information there to help the flight engineer to make what other decisions he has to make.

In the area of air traffic control, the focus of our research today is on a terminal configured vehicle program. As Del Fadden mentioned a minute ago, Boeing had worked pretty hard at that five or six years, and we at Lockheed have been involved in that for the last couple of years. It's a two pronged effort.

The Lockheed-California Company centers on near term research. We are interested in looking at studies, at systems and paying information which will help to build more in the long term direction. And the end point of most of the work we are doing is the flight testing on our L-1011 in house flight test

airplane. The Georgia Company on the other hand is looking a bit more in the future.

The advanced cockpit that you just saw is typical of the sort of thing which they're identifying as hope that as we make progress in understanding the ATC interfaces and some of those tough system applications, the Georgia people will take the information we gained and come up with an optimum interface with the operator.

We plan sometime in the mid '80's to take a very moderate cockpit which they're designing, put it in our in house airplane and fly it around, get a feel for what they have in store for us.

Incidentally, the Lockheed-Georgia Company is working closely with NASA Ames and NASA Langley and those three organizations are trying to upgrade their facilities in these area simultaneously.

One of our goals is to work in the area of total four dimension flight. Right now FMS on a 1011 does a 3D job. It flies through space and navigates and descends and gets to the airport automatically. In a sense, it has 4D capability. It can deliver you to your destination point within a couple of minutes or so. But 4D, as we see it, is something a bit beyond that. We would like to arrange our flight management systems so that it flies an airplane, delivers it to the destination point very accurately and very much in agreement with what the air traffic control system is trying to do. We, a year ago in August flew to the Dallas/Fort Worth Airport and demonstrated a prototype experiment that with a little bit of software changing, the L-1011 could fly all the way to Palm Dale down to Dallas/Fort Worth Airport and get there within seconds of a predicted arrival time, but much more remains to be done.

Here are some of our objectives. Of course, we want to maintain an optimal flight path in our 4D flight; and today we are concentrating mostly on the automatic descent part of it. We're looking at automatic, direct lift control from altitude all the way down as opposed to descending clean and occasionally using the throttle which might provoke engine wear. That is not too much of a human factor's issue. We want to use segmented wind profiles, which would be an improvement over our current linear wind profile. Now by so doing, we think we can deliver our airplane at the end of the trip point within about eight seconds every time. This may be a human factor sort of thing. If the

error dispersion is larger, one plane is late, the other plane early, then their spacing will be impacted. We don't know what the best dispersion is but for now we're working in that ball park. We think that it's obtainable without too much trouble.

The real problem with 4D flight is integrating it into the air traffic control system. There is a metering program which has been pioneered at Dallas/Fort Worth Airport and at Denver. It's a time base metering concept that is going to be spread around the country and probably the next year or so you'll see another 18 or 20 airports. For today we are trying to make our FMS system fit into that kind of metering scheme because we think that's what is going to happen next. The job though is not quite as simple as it might sound at first. There are a number of problems, for example, the approach geometry to airports. We would like at the end of our computer descent to jog with the metering fixed point at the airport, but the airport people like to keep their metering fixes as far away as possible to the airport to have room to maneuver and that starts making it happen at a higher altitude. We have great procedural changes to solve the ground controllers handling airplanes in a certain way. We would like to make as few interruptions or changes as possible to have our equipment fit in with the way it works normally; however, we would like, for example, to find out the metering fixed time to which a controller controls the airplanes in a sector. If we had that, we could put it in the computer and deliver the plane there exactly when he wants it. But his metering fix time is computed by a ground computer. It makes a different computation than our airborne computer does. If there is a little difference in the two, we can build in the flexibility to account for it. If there are big differences though, then we've got a problem. And the problem goes like that. We're working quite intensely with Fort Worth Center and had great cooperation from them. They seem to be quite interested in what we are doing, have given us a lot of help; and we hope by next summer, we will be flying 4D flights again. And sometime in the fall, we would like to get back there and see if we along with that, we can explore the use of data link. The voice com between the airplane and the ground may get a little heavy particularly if we ask the ground to tell us what the wind velocity



is at every 3,000 feet. We think a data link could do a lot of good there. We would also like perhaps to transmit our estimated time of arrival; and if on the way toward the airport it changes for whatever reason, to have the controller give us a new required time of arrival. We put that into the computer automatically and get there when they expect us there.

Another thing we are looking at is traffic display of information. And the subsequent charts all discuss that a bit. For the flight test, we will be using an updated version of our FMSRM computer to do the 4D flight management task.

We are making use of a spurious display. We had a black and white display, which you have seen on a previous chart. Now we want to get a little bit more into tune with 1980's technology and go to color.

Delmo Victor Corporation of Northern California is supplying information which will sense where other traffic is, and we want to make use of that. We are going to do some flight testing early next year to see how it works. If it does work, we would like to bring that up on a color display perhaps as we enter terminal areas, and it will start to take a look at some of the tough questions of how to use cockpit display traffic information.

Teledyne and Lockheed have been talking about using ACARS. We would like to use the ACARS system for data link. It may not be the final data link system for ATC problems, but it's an opportunity to see how data links feel for our application.

For the data link, there's another interesting possibility. American Airlines flies 747's around the country, which collect wind data all the time; and they transmit it down their ACARS. They do this under contract for NOAA. A couple of them fly to the Dallas/Fort Worth Airport every day where we would like to visit again. And there is an interesting possibility for data which they would down-link during a descent to give us a sort of accurate wind profile that we would like for our descent. So when we come along a couple of hours later, we could up link the wind data automatically, put it in the computer and follow the plane landing. Similarly, with an estimated requirement time of arrivals, we could make use of ACARS network to make that happen.

This is something which is not cast in concrete. We're not covered by contract. We are talking to Teledyne, talking with American Airlines, talking with Fort Worth Center trying to see if we can work something out.

For the display of cockpit information in the airplane, we are working with the Delmo Victor Corporation of Belmont, California; and in December we plan to install their gear in our inhouse 1011 and with that, operate in the L.A. area as part of the normal flight test in the airplane. We would like to see how their system works -- how effective it is in picking up other traffic. Now the way it works is, as ground radars rotate and paint the various airplanes in the sky with their beams, they excite transducers, ATCRBS transducers. They transmit a signal.

The Delmo Vector equipped airplane process the signals and then displays the other traffic on a screen that looks like this and is capable of finding the azimuth and range of the other aircraft. Now this will look something like what we are going to put in the plane for phase one or the first part of the study, which incidently is being done under a NASA sponsorship. This is NASA-Langley. We have a small contract with them. We will look at a three-inch display supplied by Delmo Victor. It's black and white. We are going to look at a 20-mile diameter on the display. Our own ship is the symbol two-thirds of the way down from the top. The A's are aircraft equipment mode A transponders. We don't know what their altitude is, so we bring up an A. The C transponders, our first blush look at this thing, will be represented either as above or below us. And we plan to run some experiments with different altitude envelopes as an attempt to see how this sort of filter algorithm would work.

Now what we want to do eventually is to pass from that little three-inch black and white CART to a color display. And as my colleagues from Boeing here probably noticed, this is a display of the Seattle area. We want to bring up the CDTI information on this sort of display. A lot of work remains to be done to figure out what the scales should be, what symbols should be on it, etc. and we're talking with the FAA. They're doing some extremely interesting work in that area, and we're going to be in touch to see if we can't make our research coincide with what's needed to solve this problem.

In conclusion, I have two very general conclusions but based on our experience of Lockheed, we think there's good reason for them. We think that human factor's functions should not work in isolation. We think that it's very important for tackling these airplane ATC problems that the human factor's people work very closely with system designers and developers. Similarly, we feel that the research that may come out of this workshop is something that should be shared by industry, by government -- I should have a third in there, by academia. We think again that industry has particular contributions that can be made, we think for example, we're good at taking rather near term technologies, rapidly putting them into operation, working out some of the test operational bugs that come along with it. On the other hand, universities have, from their point of view where they can look a little ahead in the future, look a little more into purer science, that sort of thing, do a great job in that area. And of course, there is a lot of overlap in between. At any rate, we feel it should be a team effort between industry, the academic world and the government agency.

As far as Lockheed's contribution goes, we have some experience in aircraft systems. Automation, I suppose today there is probably a hundred to two hundred thousand fully automatic landing made in commercial service. There are questions which came up yesterday, the ALPA fellows mentioned that there are questions which always persist with increased automation. What do you do when it does work? Well, there's really quite a body of experience out there which can discuss some of these things.

We are informed in advanced cockpit design and development. This is a particular strong point of the Lockheed-Georgia Company. We are involved with the air traffic flow control integration. This is mainly under the egis of the term of control -- configured vehicle program at NASA Langley. And I mentioned that we feel this is a very modest program. It doesn't allow us to do a whole lot of flight testing and things we like to do to really accelerate this technology application. And consequently we feel that it might be a very fertile field for increased funding that might result as a consequence of this workshop.

The system monitoring and maintenance area. We are getting very heavily involved with such things as our FIDDS system and those things are going to go into commercial service within the next couple of months. We would like in subsequent smaller workshops or whatever, the process for what ever happens today, to be a participant. These are some areas where we think we might have something to say. Now if we had the good fortune to continue some of these research matters under the sponsorship of this human factor's group, we would be perfectly willing to take those in the community of researchers that are interested in such things, take you out of this cold Boston weather, take you to the west coast, fly in the high Sierras and the coast. I think it might be a very successful collaboration. That is my presentation.

MR. LOWRY: Thank you Dick. I would like one of each for my Bonanza. Now from our McDonnell Douglas team. I believe Dr. Dick Gabriel is going to kick it off.

DR. RICHARD F. GABRIEL

Thank you and good morning. Most of the other people have said that they enjoy being here and participating in this workshop, and I guess I would like to second that feeling. I think there is a great deal of potential benefit that can come out of increased communication between the various phases of the segments of the industry, and I really hope this thing comes up with something important.

This is a McDonnell Douglas viewpoint. Now the early phase of this speech will be McDonnell Douglas and some of the later phases will be more oriented around Douglas. A little overview of the discussion this morning, we are going to stop all the suspense and come right out and say, we support this kind of activity. We want to see it go forward and really have something significant with real importance for the future happening. I'm going to give a brief description of the Douglas human factors efforts, go in intensively into one specific program, the head-up display effort.

George Jansen will specifically address the flight test phase of that program, the developmental phases for the - 80. Then we'll have some general comments regarding the FAA program as we see it and some conclusions and recommendations.

Some of the reasons for our support are expressed here. I don't think that will be news to any of you people that have been working in the industry. And as I look around, I feel a little foolish up here. Most of you know this stuff at least as well as I do; but the accident record, of course, is -- emphasizes the human factor consistently throughout all the phases of aviation. It needs to be addressed. The one thing that has not been reduced in terms of the overall accident rate, is the human factor related accidents.

We're going through a revolution in cockpit design, computer automation, advanced displays, things that desperately need to be improved, increased human factors participation.

New operational requirements make it more difficult for the pilots in many respects, the limited visibility perhaps, the noise of abatement procedures, the increased fuel efficiency requirements and so on. More sophisticated aircraft features that are trying to make a better and more efficient airplane such as relaxed static stability, multimode autopilots and so on, do in some ways increase the complexity of the job for crews. Air traffic control issues which have been with us may be going to get worse although hopefully are going to get better. Certainly automation if properly incorporated can make it better. The airport congestion is with us. There are some things that are being proposed that might make things a little more difficult for the crews unless we take proper corrective action. And, of course, the ongoing and continuing communication problem. Anybody that flies into New York understands, crews can have problems if they're not from the New York City area. Foreign crews coming into any place in the United States that don't speak English as a native language have problems, and U.S. crews going over seas must have a similar problem.

Now a little bit about the background of Douglas in McDonnell Douglas specifically in human factors. We have been at it for a long time. Those of you that have been around a little longer than I have can remember the ANIP,

the Army and Navy Instrumentation Program. That program was started in the early '50's, and it's intent was to develop a system that would indeed automate and improve the cockpit display of information. It's the grand daddy of what we're seeking today. First time we had pictorial displays really represented, including the moving map displays, the first time of extensive use of push buttons and computer based systems on the flight deck. That thing came to a combination about 1963 after about ten years of effort, and ended up in a AAAIS aircraft. That's Advanced Army Aircraft Instrumentation System, a light aircraft which had this advance concept on one side and went through an extensive series of flight tests.

We also, of course, have an extensive background in commercial aviation. Human factors has been applied into commercial aviation increasingly with every new aircraft program. Relative limited participation of the DC8's, increased participation of the '9's, intensive participation in the '10's and more intensive in the future.

Military programs have been a constant source of information and emphasis in human factors. In order to be competitive in that field, we have to satisfy the military services in terms of their requirements. That's the first time that we really had some teeth in the human factors. If I can remember back even five years ago I don't think that much of the commercial aircraft industry as an "out there" industry had a great deal of interest in human factors. They did not recognize its full benefits perhaps.

In the last five years, I have seen a tremendous change in the attitude of the operators and pilots in the commercial airliner field.

Military programs such as the F18 are coming along and are leading the development of some of the advanced concepts. The F18, for example, has a completely CRT cockpit except for backup displays. It has -- the only VSD it has (or vertical situation displays) is the head up display. So some of those military programs do feed over and help us greatly in terms of developing the concepts and developing the understandings and developing the confidence in some of these advanced concepts.

Space programs, of course, both McDonnell and Douglas before they merged and since then jointly have emphasized a lot of factors in human factors, less perhaps in the display areas, more in terms of some of the more exotic problems, of weightlessness, but also impact and contouring chairs and comfort and some of the things of that nature, which again has a transfer value into some of the commercial applications.

Some of the key notes of the Douglas approach to incorporating human factors into our programs. Of course, like our friends at Boeing and Lockheed, we have IR&D programs, that's internal, research and development monies. At Douglas, these are split across the disciplines. Some of the programs we list up there (referring to overview) are human factors cognizant. There are other groups that have cognizant programs that we support. So the IR&D programs are really very important. It gives us a chance to do some of the research that is necessary to develop a reasonable concept.

Of course, C RAD, it's been noted here by Boeing and Lockheed both that they have C RAD programs, things like the FAA caution and warning system studies that have been a two-year cooperative program between three companies under FAA sponsorship are creating, I think, advanced concepts, something that really will be a sufficient improvement for the cockpit of the future. At least some guide lines that we can work for to increase the standardization and perhaps improve the utility of those systems.

Other programs, just to show you a little bit of the scope, are not all cockpits. We're currently working on advanced crashworthiness problems associated with structures. We have a contract at Douglas in which human factors is participating, trying to develop improved crashworthiness features of the structure. It's important to know what factors or features in the aircraft once we do have an accident are important in the survival of the passengers. Is it a piece of structure that is giving us the problem? What is the behavior of the occupants? Do we need better restraint, etc, etc, etc. So all of the activities that the companies such as Lockheed, Boeing and ourselves get involved in are not directed strictly to cockpit. And I think there're important issues that we must keep in the perspective.

Once we establish a program, are going ahead with the development of aircraft, we followed the procedures that's listed up there (referring to overview). The first thing that happens after we get the program kicked off is the establishment of a multidisciplinary cockpit committee. That is chaired by the chief project pilot, and it is staffed by members of each of the major disciplines, avionics, human factors, electrical, interiors, etc. And that is an active committee. They do try and coordinate the systems through the cockpit committee.

We try to get user involvement as early as possible. Of course, we are talking with the airlines and managements. We do have an awful lot of interface with the line pilots too, which I'll get to in just a minute.

Human factors specifically, other than being a member of this cockpit committee, participates in analyses, scenario development, functional analyses, workload analyses. We participated in the definition and/or review of specifications before they go out to the vendors. We participate in the vendor proposals and evaluation of them.

We support the troops on the floor that actually put the lines in the paper that end up in being parts by helping the concept definition, reviewing the work periodically as it progresses. We get very heavily involved in some of the traditional human factors, things like work space layout, panel layout, displays, controls concepts and information requirement and so on.

One of our important roles, I believe, in the human factors participation is the test and evaluation. I am a psychologist by background. I have a healthy suspicion about what we -- how much we really know about human behavior, and we try to emphasize doing test work either in part task or full task simulation to really put some validation into our judgements.

We participate in other areas, in evacuation systems, interior design, things like that, whole broad range of activities including such mundane things as placard design.

One of the first things that I learned when I went to Douglas and wanted to start participating in support of aircraft programs -- and this was early in the days of DC10 -- was talking to the Chief Design Engineer at that time for the DC10 program, a gentleman by the name of Harold Adams. And I went



into his office and said, "How can human factors be more effective?" and he said, "How much time do you got?" Well, we spent about two and a half hours talking. One of the things that was really very important at that time to me that he mentioned was that human factors people in that generation or that era spent too much time worrying about displays and controls in his judgement. He said generally we had the Sperries, we had the Collins, we had the Bendixes and customer airlines come in and they sort of picked and chose which particular display they wanted. We had a standard cockpit configuration, but that is not necessarily what got into a specific customer's airplane. He said that the display that I think we need to work on most are the placards. There are literally thousands of placards spread around that airplane. And some of the placards are incomprehensible to the type of people that are out there in the real world depending upon them. So during the DC-10 days, we got very heavily involved in placard design and trying to improve the information flow, the display of information to both passengers, maintenance people, etc.

Now I mentioned a few minutes ago that we do try and take advantage of the crews out there in the real world. And there are a whole flock of ways that we do that. Some of them are listed here (referring to overview). We do perform interview surveys of the airlines. Now that is not necessarily the line crew, it's the manufacturing -- excuse me, the managment.

We do a lot of customer interactions, both on having people come in and visit us or us going out and visiting them giving them briefings on new concepts. It constantly goes on with all the manufacturers and the customers. We have had, perhaps not as many as we would like to have but considering series of ALPA committee briefings, head up display briefings, whole flock of specific committee members that have come in and reviewed our work, we had an exchange of information with them.

Crew training activities. It's a constant activity. Boeing alluded to this, Del did a few minutes ago, the fact that generally when an airline buys our airplane, the initial cadre is trained by the manufacturer and then for a number of airlines particularly the smaller ones. We may do all their training for them; so we have a constant flow of information and understanding of the line crew out there, what his problems are, what his needs are.

We have a customer revisit program. This is a specific program where our flight crews go out periodically, visit customer airlines, fly the line with them a little bit, interact with them and frequently provide a report back to the individual line in terms of things that they noted or observed trying to help them wherever we can, to help them improve their operation.

Customer line support. We have crews that are in various parts of the world that are actually flying in airline positions for three months or longer, might be flying in some direct line operation with an airplane.

Simulator evaluations of advanced concepts. There is a constant flow of pilots sent to our facility to participate in some of our simulator evaluations. This again is a very useful source of information.

And, of course, we have advanced concepts demonstration flights such as the head up display of verbal warning system, things like this where we get specific senior pilots, perhaps more often than some of them, generally line pilots to come in and fly and give their judgements on the concepts that we have displayed to them.

Some of the representative R and D programs that we currently have are listed there (referring to overview). George Jansen will talk about HUD, as I mentioned earlier.

We are intensively involved in vertical situation displays. I'm not going to go through a lot of slides showing you the various formats and concepts. I will express a concern that with Boeing inventing their particular formats and Lockheed inventing their formats and Douglas inventing their formats that there is going to be some attention that is necessary to pull some of these things together to get a little standardization so that crew transition difficulties will be minimized.

Horizontal situation displays, you've seen several examples of those. Caution and warning displays. EMADS which is the acronym for engine monitoring and display system, that is one we are working with G.E. and have had about a four-year program with them on that. Several simulator evaluations, we still have one to go and that is to compare the performance of the EMADS concept with conventional, make sure we really have something. We now have a format that we are comfortable with. But the real issue that is there, does the thing buy anything. Does it result in an improved performance and

without that comparative study, we won't be able to answer that with any confidence.

System status display is a recent contract that we just got as part of the TCV program to look at the flight engineer's concepts and try to do a little bit better job of automating the flight engineer position.

Some of our advanced control activities, primary controls looking at side stick controllers, center stick controllers compared to the yoke trying to give ourselves enough confidence that maybe there's a better way than that yoke. It does present some problems.

Computer input devices. Key pushbuttons are one way of doing it. I have a distinct reservation about some of the keyboard type things. I think ALPA mentioned it yesterday. That's a head down activity. And it may be a little more intensive and time consuming than we might want plus the error rate is possibly high even with a scratch pad. So what are the alternatives? Can we come up with better alternatives? Speech interaction system, of course, is one. I think that is a long way away. What are we going to use the next one for? Well, the basic point here is, we're looking at those to try and find better solutions than are currently existing. The touch panel may be a good way to go in some respects.

Workload assessment methods. We started our workload programs back in 1969 and it didn't fall out of a commercial airplane, it fell out of a military airplane, the AWACS. You think trying to define crew size for a three-crew airplane is tough, try and define a crew size for 20 or 30-crew aircraft. So we got started in the crew workload assessment early, recognized the problem of the mental workload and have had an active mental workload research program going on since 1970. We've looked at an awful lot of possible ways of assessing mental workload including currently EEG's peopleometry and things like that. None have been very successful, some of them have promise. We've also, of course, done the analytical type of workload assessment, very similar to the Boeing approach.

We are currently involved in cabin safety and efficiency trying to improve the survivability of the cabin interiors. There is a lot of ways we are going about that, and one of the key notes about that approach again is, we are going out and trying to get a chance to talk to the girls in the

flight -- I shouldn't say girls anymore -- the flight attendants and get their viewpoints and get that into our approach.

The advanced maintenance information concepts. We've done one study a few years ago in which we demonstrated that simply by improving the format of the information in the maintenance manuals, we can reduce errors a significant amount and try and promote that kind of thing. A lot of work can be done in manuals. There is a tremendous human factors problem and a lot of the information, storage and retrieval system, which we currently use, is manuals.

Our HUD program again followed the particular pattern. It was a multi-disciplinary team, avionics, human factors, flight ops and, of course, some non-Douglas agencies, a lot of interaction with the FAA, NASA, ALPA, etc.

We have had a 13-year effort to date. It's been almost a continuous effort. There have been a few short pauses, but the effort has been almost continuous.

Now the R&D involved a whole variety of techniques. These ones, those of you who are in the business or have a scientific background or an engineering background recognize very readily. But these were all gone through and they're still going on, analysis, laboratory studies including human factors, laboratory studies of information, display characteristics and so on; definition of information requirements through surveys and analytical efforts; part task simulation in a facility we call the DETAC or digital electronics technical analysis center which is really a part task simulation. Full simulation which has been an extensive series of programs and more impressively a hell of a lot of flight tests.

At this time, I would like to turn it over to George and let George tell you specifically about the DC-980 head up display effort.

I planned that real well. This way I get two hands because I'm coming back.

GEORGE R. JANSEN

I'm in trouble already. I didn't read the checklist, and I don't know how to turn the light on in the night black cockpit. We'll allow 30 or 40 seconds for eye adaption.

Really what I wanted to cover is to explain a bit about the past program where it started on the HUD. It comes to mind that HUDS are not entirely new. I think they started in the late '30's or early '40's when they put the gun site on a combining glass or a glass in the windshield. I think we're now progressing to where we can indeed improve flight safety through the use of a head up display.

We made our first effort with a bit of simulation and actual flight article on a series 30DC9 in the '67 to '69 time frame. After considerable evaluation, we came up with a symbology that was primarily the flight director inputs put on the combining glass, but in lieu of cross hairs or an individual B bar for guidance. We found that everyone seemed to like the circle dot presentation kind of taking it, I guess, from the gun site. And it seemed to work quite well.

At the completion of the development of that installation, we ran a series of demonstration flights where we got a lot of airline people, ALPA, other company folks in to just take a look at the philosophy behind head up display. Some 37 pilots from 23 different organizations participated in that program.

During the DC10 development cycle autoland program, we had three different configuration HUDs in the airplane from time to time again looking at symbologies where the HUD seemed to have the most practical application from the standpoint of safety. It was apparent with HUD while operating in the terminal areas that when traffic was called out, it was much easier to pick up and detect and at times from looking through the windshield and the HUD, we saw traffic that wasn't even called out.

In the '75 to '77 time frame, we were in competition with our friends up north on the STOL program. And when you are trying to put a hundred and thirty five thousand pound airplane on a two thousand foot strip, it becomes apparent that touch down dispersion can be a big factor. We felt that some form of head up display with guidance was a requirement and initially -- I shouldn't say initially -- we installed a VAM in the airplane and later added additional symbologies for go-around and that type of thing. At one point in the program, we were told that we had not really looked at touch-down dispersion. They were not convinced we could put this thing in a two thousand foot strip consistently. So we put a mark on the runway using the HUD, made

12 approaches and landings. Six of them were all engine failures at some point during the approach and on all 12 landings, the airplane touched the ground within the fuselage length of the airplane.

Now that STOL airplane was very fortunate in that flare was not required. The rate of descent on final was such in ground effects that you just maintained your altitude and it plunked for you very nicely, but I think really visually you could never do a thing like that. So all of these programs evolved into the latest program that we have conducted. We are still working on it. And I think it's been a very productive program.

In our motion base simulator, over 100 pilots have participated in flying the HUD to evaluate the ability, the symbology, how easy it is to fly or difficult it is to fly and all of these people have made valuable inputs to the final article. On the simulator, we flew over 240 hours with over 400 take offs and over 900 approaches and landings. In the airplane itself, we have had some 68 pilots through the airplane who have had an opportunity to view the HUD and comment on it. They were from 14 different agencies, and we have used some 63 hours dedicated to nothing but HUD in the program. To this point, we have made 146 takeoffs and go-arounds and over 184 approaches with the HUD system alone.

The objectives of the program as defined were primarily to monitor the airplane and the autopilot performance during IFR operation, to enhance the visual cues below decision height through the flare and during landing roll out. We wanted to provide take off and go-around guidance with the system and in addition, and in my opinion from the YC15 operation provide assistance from visual approaches. If you don't have an IOW, in my judgement, this system provides an excellent tool from the standpoint of evaluating wind shear early on. By that I mean, if you have stabilized where you want to touch down on the runway, the airplane is stable, the air mass changes. In my mind, when I don't have this tool, I may say, "Gee, I think I'm going along. Gee, I think I'm dropping short. Should I do something? Let's wait and see." With this symbology, you confirm what you think is happening or get a leap term on it immediately. I believe it's an excellent safety tool.

And we wanted to provide guidance for manually flown IFR approaches down to the category II.

The development criteria that we used was to keep it simple, provide the required information but no more; keep it uncluttered, that it had to be intuitive in its use by design and there certainly could be no ambiguity or confusion between head up and head down. This merely is used to depict one of the modes. This is the IFR mode with an IOS. The rectangular box is the window with the side of the box being the displacement of the localizer to the category II window. The two horizontal pieces of the box are the top and the bottom of the deviation. The dot in the middle is the command dot. The circle with the wings on it obviously are the airplane symbologies that you overlay on the dot. The 135 is the approach speed. The 300 is your altitude, and it can either be baro or radio as selected by the pilot for a particular approach. The horizon, the V is a heading bar and the little tail up there is the altitude of the airplane.

As the airplane gets down to flare, altitude is retained until speed or until flare is initiated. Then it disappears, as I recall. Speed is retained throughout flare and rollout. The localizer and box is removed, and there is a flare command that comes in. You merely keep the airplane over the dot and it will touch you down on the runway very nicely after which it goes into a rollout mode providing runway sideline information on the display. And speed is retained during the rollout on landing.

The current status of the program when the airplanes were initially delivered, we had the capability to monitor autocoupled approaches and go-arounds were approved for continuation of the approach below DH for lateral situation display, flare command and rollout command. The program is continuing and before too long, I'm sure we expect to have the system up for an approval for category I and II, guidance for approaches, for manual operation and guidance during takeoff and go-around and we're in the process currently of validating the VFR mode. With that, back to Dick.

RICHARD F. GABRIEL

We'll turn now to a brief assessment of the Proposed program, FAA/DOT program. One of the things we did when we got some of the information about the program was to look at the prospectus and the other letters that came along and try to assess the comprehensiveness of the program. If you look along the left column there (referring to overview), those general approaches, selection/classification, training, etc., there are at least five ways we can

improve human performance, which I think is the goal of this program.

If you look across the top, you can look at types of people that are involved in this general area of aviation operation. So we look through and said, OK, what things did the prospectus seem to emphasize and what things did they mention and what things were ignored. Here in this little chart is a fall-out of that. One thing is notable by its absence, it seems to me, and that's the cabin crew. We pretty well ignored the cabin crew.

The other thing that seems apparent to me is that perhaps maintenance although mentioned hasn't been really addressed in any depth, and maybe that needs to be assessed a little more carefully. In general, though, I think that the FAA has done a pretty good job. They have identified performance enhancement methods. They did look at motivation, at least for the cockpit crew and ACT, and that is an important factor in getting immediate performance improvement. The general comments about the program after reviewing the information are that in our judgment, we want to emphasize that the program should be balanced; but we heard a lot about advanced concepts this morning. We have got many thousands of airplanes out there that are not going to be impacted by what we are talking about today. They will be the bulk of our transportation system for a number of years to come. It seems to me, we should keep our existing aircraft in mind; what we can do to improve their safety record? That should be an emphasis certainly at least equal to trying to come along with better ways of doing it in the future.

The second thing, and I think Lockheed alluded to this, is that we think manufacturers should play a more active role than perhaps is apparent in the documentation that's been provided so far. The reasons are expressed there. We do have experienced multidisciplinary teams that have been at this job for longer than almost anybody. We have an awareness of the factors that are involved in the operational world and in the design and under consideration in the design of the next aircraft. We do have facilities. And one thing I think is important but may be subtle, if you are working on something, you get yourself convinced of it, it is apt to get into the design. There is such a thing called NIH, not invented here. If it's being imposed upon you, you are less apt to give it perhaps the full hearing it deserves or warrants. So get us equally involved in the thing, and I think it will be one of the best ways of getting the good things into the system. We think there needs



to be a real definition of performance standards. Some of our current problems today are because we don't have performance standards. We are reporting to that comparative evaluation saying, is this better than that instead of saying, here's what we have got to design to. Let's get that level of performance. I don't think we have to wait for the ultimate standard. I think that we can at least work with some interim standards, give us something to shoot at that we can recognize, that the industry can accept, and maybe one of the things that can happen with this particular program is that the various segments of the industry working together can sit across the tables on a continuous basis. Let us get that doggone thing hassled out and see if we can't meet some good, perhaps not just common sense, standards for the near term and then go for the more intensive, expert, experimental outcomes a little later on. We must never forget that human factors is only one segment of that design.

The best airplane is the best series of compromises. If I am in the human factors business, I have to compromise there. There are conflicting requirements even within human factors. There is a standard for a tape display, but should the top number go on the top or the bottom? And which way does it rotate? It was mentioned yesterday by ALPA, there are two conflicting human factors principles there, and it isn't easy to come up with the proper answer. In either case, you're going to be violating a human factors principle, a valid human factors principle. So that's true all throughout design, and we must accept compromise one of our standards because it is a necessity found throughout the whole system.

I think that my further comment would be that I would like to see the program scope expanded to include the in-flight injuries and the post-accident arrival. Unfortunately, I don't think we're going to continue forever without an accident, no matter how good the systems are. And I think we need to address those situations that are currently giving us problems. There are more in-flight injuries than any other problem we have. Of course many of them don't die, but they're injured, that's pain, suffering, problems.

Now, my recommendations for specific programs. Those were general comments. Now I'm trying to get a little more specific, and I don't intend for you to think these are all the things that need to be done; but I think I noticed a lack of attention to some of them perhaps in the plan. I really think we need to do a better job with the existing data. Take that structural

crashworthiness program we were working on a little earlier. Try and find out what causes accidents, what has been the cause of accidents. There is very little collation of the accident data experience. There are some powerful techniques that might be used in terms of intensive accident analysis to try and give us some trends, to give us some guidelines of what are the really important factors.

Currently we have to look at each and every accident, accident-by-accident, look at the postmortems, and they're sort of hard to come by, to find out what killed people, try and collate those for that accident and then try to collate them across for a series of accidents. There are some general scenarios for accidents. But it's sure hard to put all the facts together and come up with some conclusions. I really think that's true not only in the structural crashworthiness things we've talked about, but also what were the real causes of accidents other than crew error. We sometimes stopped right there. I think it's understandable why in the past we have stopped there, but I don't think we can do it anymore if we're really looking at accident experience as a real way to give us guidance of how we can do a better job in the future.

ALPA, I think yesterday mentioned the fact -- C.O. Miller mentioned that we need a little better information about the accident investigation team and what is the date of the accident investigation is going out to get, training those people and getting consistent data of cross accidents. And I think those are all warranted comments.

There are other sources of information, the ASRS we heard about yesterday, and I certainly support that program. I think Douglas does. I'm not just talking for myself today. This has been approved by my vice president.

Crew surveys, I don't think we have done as much of that. Formalized crew surveys, I don't think we've done as much formal crew surveying in the past as we could have. I don't mean just the interviews, but documentation. Of course, the crews have to be willing to sit down and respond to a questionnaire occasionally and sometimes that's difficult. I know of one gentleman who sent out a survey to a group of crews, sent out a hundred questionnaires, didn't get one back. That didn't happen to be a commercial program, that was a military program; but we need to get the support of the guys out there to give a better feedback.

I think a thing also we can do is to implement some known improvements that already exist. The SASAG, the Special Air Safety Advisory Group that the FAA had a few years ago that involved six highly eminent retired aircraft captains came out; and as their number one item, identified the vertical guidance as a most significant problem. There are ways of providing that vertical guidance visually. The head up display, of course, doesn't require anything on the ground. I would like to see us emphasize getting some way of incorporating vertical guidance, visual guidance into the approach. That's where our biggest accident experience is.

The second thing that I think we can do is we all appreciate the effects of runway gouging. It's expensive, but it does help the overshoot problem and that is a significant problem, not so much in terms of deaths but in terms of number of accidents, a lot of equipment, a lot of injuries. That is the existing solution that we're perhaps going to push along a little faster, and there are probably others. I just think we can talk about these things, and we have talked about many of these things for year-after-year-after-year. I would like to see this program just not talk but really go out and get something done, and I think we can do it.

Air traffic control, everybody is concerned about air traffic control. I don't think I need to say anything more.

Crew workload, the role of the crew which is changing, perhaps in an unorganized way. The automation, we've talked a lot about those things.

Methods of directly improving crew performance. Maybe we can do a little better job there. One of the things that occurs to me is that, as a psychologist, motivation is very important. And one of the key factors in motivation is feedback. Are there some ways we can get feedback to the crews in a better way than we currently do. Without feedback, you're not going to get much performance improvement. With feedback you get dramatic changes in performance improvement. How do we get the feedback to the crews so they can know how they're doing and take advantage of that knowledge?

In conclusion, I think that the identified program goals are valid and obtainable. We noticed an emphasis on performance criteria, performance standard, and design guidelines. I think all of those things are valid and meaningful goals. We do, as I mentioned earlier, encourage the broad participation of all

the industry. We certainly intend to give them our wholehearted support. We do want to emphasize the need for specific plans and programs, real objectives, schedules, making sure that we're getting somewhere, making sure it happens and gets implemented.

And as I said before, I think that overall McDonnell Douglas supports the concept.

Thank you very much.

(Coffee break taken.)

SESSION 3 CONTINUED

MR. LOWRY: Well, it looks like mostly everybody is, at least the major portion, are here. Now it's your turn. You know the ground rules. Remember we have the two mikes on either side. Please state your name and affiliation, so we will get it into the transcript. Other than that, if you wish to address a question to anybody specifically, feel free; if not, have that in general. We'll try to pick it up from there.

DR. MOHLER: I'm Dr. Mohler of Wright State University. I would like to ask a question of Dr. Gabriel and Mr. Jansen to give some specific information on how airline pilots were involved in the McDonnell Douglas certification of aircraft?

MR. JANSEN: I think I would respond in this manner: On the original DC9 development effort, ALPA had a committee that came to the factory on several occasions. They indeed wrote quite a comprehensive report on their effort. They did have a number of suggestions which were made during the early stages of the program and many of those were incorporated in the design at that time.

MR. LOWRY: Another question?

MR. WHITCAN: Dick Whitcan of the New York Times. You people are the manufacturers. Can any of you give us an explanation as to why, with so much material available on altimeter error accidents and with the military having abandoned the drum pointer altimeter long ago, why are we still turning out aircraft with the difficult altimeter?

MR. LOWRY: Anybody in particular want to pick that up?

MR. GABRIEL: I'll take a whack at it. To my knowledge, we are not still turning out aircraft with the drum pointers. DC 9's, DC 10's, at least the DC 9-80's, have the counter drum pointers. We haven't put a drum instrument in that airplane, in a new airplane, for a long time.

MR. WHITCAN: What do you mean by a new airplane?

MR. GABRIEL: A new version. A 9-80 or --

MR. WHITCAN: Well, you're with McDonnell Douglas.

MR. GABRIEL: I'm with McDonnell Douglas.

MR. WHITCAN: Isn't Boeing still turning out the drum pointer on the 727-200 coming off the line?

MR. GABRIEL: I can't answer that question specifically, but there is a problem if you change the indicator, then you'll have loss of standardization and that also presents problems. That's one of those areas where no matter what you do, you're sort of wrong. If you lose standardization, there's a crew retraining problem, things of that nature. If you change, you may get increased readability. So it's one of those areas where there are conflicting requirements in terms of what's the best way to go. I guess anybody else have anything to add to that?

MR. LOWRY: Well, we're in the standardization business at AIA, and we look at these things from time to time; and our observation is that the customer requirement for his own personal standardization is the driving factor. If that's what he wants and that's what he specified, that's what he's going to get.

MR. WHITCAN: Well, standardization is a worthwhile concept, I'm sure. But if an altimeter says, you're at 33 thousand or 400 feet, how much standardization do you need? I mean, you get away from standardization, it would seem to me, if a display tells you exactly where you are, I don't see -- It's hard for me to understand why standardization should override that advance.

MR. LOWRY: Well, I don't think we can answer it beyond what we said today.

MR. WHITCAN: Do the Boeing people have -- Am I wrong in saying that the new 727-200 still coming off the line still has the drum pointer?

MR. FADDEN: Some do and some don't. It varies with the airline. The technology behind the two are quite different. They require different systems on the airplane to drive. The reliabilities of the various instruments are different, particularly the failure modes. I think it's a complex question that Dick Gabriel answered. It's not a comfortable trade-off, but it is a compromise between a series of conflicting requirements.

The data saying that it is misread, the rate at which it's misread, is itself not highly conclusive data. There is an indication that it is misread. Exactly how significant that error rate is, I don't think we know.

MR. LOWRY: Well, as we have seen this morning, the new stuff sure as hell doesn't have it there. Is there another question?

MR. GALANTER: Eugene Galanter of Columbia University. I would like to take advantage of the remark this morning and not address a question to the panel, if they will forgive me, but rather to make a statement so you may all relax and enjoy the meeting as much as we are.

I will spend 2 minutes and 50 seconds, if I may with you and make the following remarks for the record.

In formulating the problems and prospects of what I see here as a rededication of the human factor's efforts, we must not overlook our roots which are the basic research programs in human experimental psychology. A proper mix of basic and applied research is necessary not only for its own sake but because I believe that aviation technology will continue to develop and change, and we must increase our stock of basic information in order to support such change.

Let me cite some examples of the importance and relevance of such work. Our own studies of real life cockpit noise effects extend the laboratory : finding of our British colleagues that noise levels in cockpits reduce short term memory; for example, for crossing or descent altitudes, for turn vectors and for retaining our mental maps of departures, geometries and missed approach procedures. Furthermore, the effects probably accumulate during a flight so that these interior noise effects may, at the end of a flight, be even worse than they are at the beginning. These studies also point to the fact that popular concepts such as the much discussed here "workload concept" are merely catchall terms. Workload itself may be more correctly represented as a composite structure whose components, such as cognitive load, perceptual processing demands, verbal memory and so on may vary both independently and in concert so as to make measurements of the workload a poor approximation of the factors that reduce and enhance cockpit effectiveness, and as a result, change the error probabilities vector in the cockpit.

Finally, let me point out that there is an important literature in experimental psychology that is not yet part of human factor knowledge. The meaning, for example, of see-through displays of the functional blindness of low contrast items, that must have a lot to say about human performance during IFR/VFR transitions, and yet this literature is not well known in the human factor

areas. And additional new theories of human perceptual processes that revise our concept of information or display formats are important features of the existing literature in the experimental areas that ought to be available to the human factor specialists.

The point is that we can't make every comparison among every possible system and subsystem. We need good theory to guide our selection and testing. Thank you.

MR. LOWRY: Thank you. Next question?

MR. BERTONE: Burt Bertone, Sikorsky Aircraft. I would like to address this to Mr. Fadden. I'm glad to see that you have similar problems in seat comfort that we have in the helicopter industry. I was wondering if, as a result of your research, you have developed a seat comfort quantification method?

MR. FADDEN: Well, we developed one for the test that we did using both subjective and objective measures. And as I indicated, we got relatively good correlation between the two measures. Now we use them differently.

The objective one was not very specific to individual features but did gauge the overall comfort index quite accurately.

The subjective one gave us a better feel for the specific features that improved the design. We try to use, wherever possible, a mixture of the two. Subjective measures are just fine. There's nothing wrong with it. The pilots are really good sources of data. As long as you have a formally structured program for obtaining subjective data, we don't have any difficulty using it.

MR. LOWRY: We have one on the right and one on the left.

MR. MILLER: I would offer a comment first on this altimeter question. The position of the industry on the subject today is going to be resolved if nowhere else in the courtroom. I would hate to be the operator who flies a drum pointer altimeter the next time one of these accidents occurs.

My question, however, is a completely separate subject, which -- I'm sorry, I'm C.O. Miller of System Safety. It's addressed to all of you gentlemen, and it's obvious from Dick Gabriel's comments and others that pilots of not only air carrier aircraft but I even think some of the more significant general aviation aircraft are now something, perhaps a cross between a computer operator and a computer programmer, depending on how you want to define those



terms. I think when you talk about RNAV systems, INS systems, the various flight management systems, HUDS and so forth, you have people performing a function as Dick said, which is markedly different than what perhaps they did not too many years ago. My question, therefore, is to what extent have the manufacturers, airframe or component, performed operational hazard analyses on these kinds of systems I just described? And furthermore, who is keeping track of the kinds of mistakes that are being made in operations or in flight tests so that we have an understanding of what kind of human errors are really taking place?

I might mention that I asked this same question at the Flight Safety Foundation International Seminar in New Zealand in September, and I asked it again at the NASA Operations Committee Conference, whatever they call it, a couple of weeks ago at Langley, and the response was minimal. Perhaps you gentlemen could give us some better information.

MR. LOWRY: Dick Heimbald, would you like to take a crack?

MR. HEIMBOLD: Yes, I would like to say a bit about it and then maybe Ralph Cokely would like to say a bit more about it.

As regards to automatic flight control systems, the failure mechanisms are exhaustively studied; for example, for the 1011 there's an elaborate iron bird which was constructed at great expense with all systems replicated and the pilot had an accurate cockpit configuration, and they would fly many thousands of hours of operations with failures of all types, single, multiple failures, et cetera, introduced. Many failures were introduced on this elaborate iron bird, and the remedial actions were noted and these were improved upon. This was done with our pilots, customer pilots, et cetera.

Before we get to that stage, there are rather elaborate failure modes that effect analyses particularly for flight control equipment.

Flight control system designing is probably 90 percent designing for failures. And so we think, by the time that automated equipment gets into service, it's in pretty good shape. I would like Ralph to comment a bit on the impacts of RNAV equipment on that flight and what its operational --

MR. MILLER: Excuse me, may I interrupt a moment. I'm talking about human failures. I want to know the human failures that are cranked into operational hazard analyses and what kind of human failure data is being recorded? Maybe I didn't make that point clear.

MR. HEIMBOLD: Okay, I guess I discussed systems failures in that respect, and I again would like to ask what Ralph could comment.

MR. COKELEY: That is not an easy question but we do take into account human failures -- I wouldn't say that we are 100 percent covered, but we do punch all the wrong buttons at all the wrong times and analyze in most cases an actual flight, what the outcome of those are and to the best extent possible, all these mismanagements are designed with a soft reaction or reaction that can be coped with and that is a fairly demanding task. I think we have done that successfully on our autopilot and our flight management, which probably has a wider potential for a mismatch. To the extent that we tracked these errors -- probably we haven't tracked them accurately enough, but the big ones are the ones that are repeated and we certainly hear about and the flight management system we have made, which Dick described, has been in airline service for three years. It has gone through substantial improvement, primarily on the basis of feedback from our customers and what we have learned from the experience in our field.

MR. LOWRY: Del, can you add to that?

MR. FADDEN: I think there's three ways that we try to deal with that problem. We use the upper, inner error criteria during the test in the design phase and the evaluation and development of the design errors as well as operability and how he likes it, are key factors that go into narrowing down the design choices.

We also, as Lockheed pointed out, tried to make the design tolerant of the errors that he does make so that when you press the wrong button, you don't do something that is not recoverable. Furthermore, we try to reduce the speed with which the crew has to react through pushbutton operations. Wherever possible, and we have gone into it in great extent in our new airplanes, we avoided having immediate action that involves pushbutton, keyboard type operations. For instance, with the map display as a primary flight instrument the crew can handle the majority of routine changes in the terminal area.

at least the initial phase of that, without any keyboard operation. He's got enough information on the display or available from a single data button to turn the airplane, maneuver it in proper direction and then, if he wants to, if he chooses to because he wants more data, he can get more data up on the display through the keyboard. So by reducing the criticality of going to get the data from the pilot's point of view, the speed with which he thinks he has to go get it, we think we can reduce the numbers of errors. Does that answer your question?

MR. MILLER: I'm still waiting to see the report of somebody having given a professional paper anywhere in the world that documents this.

MR. LOWRY: You won't see it until it's finished.

MR. MILLER: Okay, I think you answered my question.

MR. LOWRY: Chap on my left here.

MR. CAMPBELL: My name is Campell in Transport Canada, Ontario. We heard some reference to some of your standardization. I would like to mention two areas and there are probably a lot more where cooperation between the manufacturers represented here would be of enormous assistance. I would like to ask the panel what may be being done or planned in these two areas. One, standardization of terminology, nomenclature and presentation and manuals and other documentation for people who are involved in a lot of airplanes. Commonality would be a big help. The second area is that of parallel programs developed similar airplane assistance.

MR. LOWRY: Well, within our aircraft nomenclature is a problem, and we do maintain a standardized list of nomenclature across all of our fleet. It's not necessarily applied by all operators because all operators attempting to maintain standardization or many operators are maintaining standardization within their own fleet. We have a cooperative program with the various airlines to establish standardization across as much of the nomenclature as possible, and we do that considering both our previous products and our new ones.

Within our systems, the systems are necessarily specific to a particular airplane. But within a technology area, we use and forcibly use the same general approach so that the operating concept is familiar and similar to the

pilot for airplanes that he's likely to be operating back-to-back.

On our two new airplanes, the 75 and 76, there are some differences in the systems between them. The operating controls are, to a very high degree, identical to the pilot's point of view. Anybody else want to speak to that?

MR. GABRIEL: Let's make one enrichment to that perhaps and that is that the military puts out some standards and specifications for abbreviations, nomenclature, et cetera, and we do try to incorporate those to the extent we can. There are some difficulties, I'm sure, across manufacturers.

MR. PORITZKY: Mr. Poritzky from FAA. I have a question for the panel concerning objective workload measures, and I think I sense a difference in view among the panel members. And I would like to hear a little more discussion. I thought I heard both the Boeing and the Lockheed people talk about the difficulties of scientifically validated objective workload measures and basically they seem to be trending toward lots of analysis, but predominantly comparative studies of workload measure. I thought I heard Dick Gabriel be a little bit more bullish on the possibility of objective workload measures, and he talked, I think, about interim objective scales. I think we've all had a great deal of difficulty with this, and I guess in the light of the comment that was made by the gentleman from Columbia, I would be much interested in hearing some further discussion of the panel's view and let me add a question to that.

Several of you spoke of full mission simulators or extensive simulation capabilities within your plants. And I'd be interested particularly in grappling with this question of objective workload measures, whether you feel that sort of work, the, particularly the scientific or -- Well, I'll leave it that way, the scientific aspects of that are best handled within the airframe manufacturers' houses or whether there is some benefit here in outside government facilities for examining some of these problems.

And I think there is some difference in view there also on the panel. I would be interested to hear discussion.

MR. LOWRY: In view of your description, why don't we go right down the line, Boeing and then Lockheed and then see if Dick still is as bullish as you thought he might be.

MR. FADDEN: The view that I was representing represents the view that we have on the activity programs. It's our view at the moment that the objective measures are not sufficiently validated to use them directly in the design effort. We are developing objective measures and following progress with other people in the industry that are using objective measures in our research department. We think that that area has a lot of potential. We want to use it as soon as possible, as soon as we know what it means.

The key factor isn't that we have workload or that we don't but that we are able to quantify what caused it or what we can do about it or see the effect of the change. So the understanding level that we need to have to make a design change in the airplane is quite a bit different from the initial concept behind some of these objective measures. We applaud the work that the Air Force is doing in that area and think that it should be continued. And we hope to use the results of it as soon as we can. As far as your question about how they ought to be used, I think the development of that, of those measures and the validation of them, should be very broadly based and should be done across the industry by a variety of people confirming the results. So we really do have confidence in them, and then I think they should be used both by the manufacturer and by other agencies. The manufacturer can use them very effectively in the design phase and needs to have direct immediate feedback into the design phase. Our ability to use human factors to its highest effectiveness means integration right into the design problem. It's a system approach. Human factors is a problem and it has got to be right there, got to be right in the design. Does that answer your question, sir?

MR. RUGGIERO: I would just like to add a small piece to that. I think there is an awareness across the company especially in the research area, as Del has mentioned, more basic methodologies and the need to develop those basic methodologies of understanding; in this case, mental or cognitive workload. The integration processes, the information processing that's going on, the decision making processes. The problem is that at this point in time we don't have a motto, a way of integrating that basic information in a manner which we can use practically today.

The bottom line is that those same methodologies, whether you are talking about evoked potential, heartbeat rate, eye scan patterns, whatever, still have to be validated somehow. You don't know if a P300 wave means anything

in that operational environment unless you can validate it. And what we found ourselves doing now is that we use the same scenario to validate it that we are using to validate our own present workload methods. And so we are aware of these methods and develop them, but at the present time, I don't think we feel that we have enough of a motto that can be used.

MR. HEIMBOLD: I guess the predominant feeling at Lockheed is that we're keenly interested but we don't know how numerical or quantitative values that we can translate into cockpit features or human interface features.

I would like to point your attention that the Lockheed-Georgia people are taking a very comprehensive approach to flight simulation management from a human factors point of view as probably as pure as you can get with what's known today. And I would like to ask George Sexton if he would care to comment on these sorts of issues and the full simulator capability.

MR. SEXTON: George Sexton from Lockheed-Georgia Company. We agree with the panel members on the difficulty of objectively measuring workload. There are some methods that are being used throughout the industry. They're primarily secondary task measurements. I think that that can be expanded to measure performance when you get to the sophistication level of the flight simulator or further into the flight test of aircrafts where you can objectively, from the crew members or from your mission analysis work, determine the high workload "sections of the mission".

And then, as you vary the environment within those high workloads, sections measure the performance in air speed, altitude, heading and the other typical parameters that are important in flying the airplane. However, that, as I point out, has to be done after you get into a tool such as simulation or flight tests, and it's very difficult to bring in the initial design process, that is, the process that we are using down at Lockheed-Georgia. We are getting as much of that work done in the mission analysis phase and through the use of flight station mock-ups, flying scenarios with operational qualified air crew as we can to sort out a lot of bad ideas that will eventually translate into reducing the crew workload when we get into flight simulation and flight tests.

MR. GABRIEL: I didn't intend to convey the impression that I was bullish about our ability to objectively quantify mental workload at the present time sake so pardon me if I gave that impression. I would like to say some comments, however, about the meaning of interim measures of workload that we might use before we come up with a good solid objective measure that everybody could be confident in. I think that's some distance in the future unfortunately because we desperately need it.

The Air Force, in some of their studies, has decided just arbitrarily that they want a workload as measured by the analytical approach of point 5 or 50 percent, whatever you want to call it, as defined by time required divided by time available, but that isn't a bad way to start.

I am as concerned with underload as I am overload in many cases. At least they got enough margins both ways to move in either direction, and I expect that there is a plateau up there sometime before performance significance drops off in either direction. Maybe that is one way to go, that we get a consensus of "experts" that can reach a consensus like that. Another way might be to take the secondary task approach and acknowledge that it has its limitations and that it isn't everywhere applicable. And we do have problems associated with it in terms of operator strategy and so on and so forth; but can we use that in some kind of an objective way and come up with a conservative interim standard? It's just a thought, and it seems to me that one of the things that this effort here, this program that we're kicking off today or these two days is something we could address. I really would like to see some standards of some kind. It would sure make our job easier, but obviously they have to be reasonably valid. We have to assess whether these standards we would propose may get an acceptance on it any better than we do it now. We certainly can't do away with testing and with doing our best possible job on design and so on and so forth, but it would be helpful to have these standards.

MR. RUGGIERO: I would like to make one further and small comment. Something that is particularly distressing to me is the fact the word "workload", if you look at a dozen different documents that use the word "workload" or listen to a dozen different people use the word, you wouldn't know that they were talking about the same thing if you asked for an operational definition. It's very important to try and separate the relationship between things like the amount of automation. This elusive measure we call workload fatigue and

stress. Optimum workloads operate in an area where you want to provide a system which allows the operator to determine how much workload he wants or needs, for instance, that's one general guideline.

I would like to draw an analogy from the sacramentary area of psychology. A long time ago -- for me, it seems a long time. Maybe for some people that have been in the field a while, it's not so long, but we did I.Q. testing, and we had a measure of intelligence, the I.Q. quotients. And we used that single number, that index, and we did personnel work. We said, if you had an I.Q. of such and such, you would be a good accountant or if you had an I.Q. of such and such, maybe you could be an engineer. Okay. Now, we began to understand that the Intelligence Quotient was really a combination of a number of factors as we began to understand the structure of the intellect. And today, anyone who uses an I.Q. quotient or index dates themselves and anyone who understands the problem realizes that what you are really after is a profile, that there are a list of parameters that go into the measurement of intelligence.

We have a theory of the structure of the intellect. It's my hope that as we better understand the problem from a systems approach, we will be able to approach workload and the measurement of workload that way. We are starting to make progress in that direction, but please don't make the mistake. It's so easy to get one little number and then run around like with the automobiles, you know, your MPG ratings so you can compare everything at the auto show. We mustn't make that mistake in this area. It's much too complicated to be lulled into that kind of a comparison.

MR. LOWRY: Thank you.

MR. SMITH: J.D. Smith from United Airlines. I would like to come back and hit this altimeter subject again because it's possible the way the record stands that some undesirable work may take place.

Early in the '70's, we did a very extensive review of incidents and accidents for the purpose of coming up with the safety awareness program. One of the deficiencies that surfaced was categorized as altitude awareness. And this is the point I would like to make a plea for, that really our problem is altitude awareness. Because if you had a chance to look at all



the experiences of altitude problems, I think you would conclude that no altimeter is without fault.

I would suggest we deal with the whole system and the barometric indication as well as the radio indication as well as the altitude alert and the oral signals that are associated with it and start to determine why, for example, altitude awareness is not being accomplished. There is no airline pilot that will intentionally violate an altitude assignment, but it is happening. So in addition to these problems down near the ground -- But here again, you have a radio altimeter as a backup, I would merely make the plea that if FAA sees fit, and frankly I hope they do, to move into this subject with consideration effort, that it be on the basis of altitude awareness rather than an individual piece of hardware.

MR. LOWRY: Thank you, Mr. Smith. I think that quite correctly states that problem, and it's -- I think you'll get a general agreement up here. Anybody else?

MR. LAYNOR: I'm Bud Laynor from the National Transportation Safety Board. I would like to take the opportunity to make a few general comments and perhaps specifically address some of the comments made by Dick Gabriel during his presentation.

First of all, I would like to say that we of the staff of the NTSB certainly support the FAA human factor program. We're very much encouraged by the assemblage of people that came to the workshop; and, of course, we're in the best position to see the results of human performance deviations. So we're very much concerned on the human factor role and aviation accidents.

It's obvious from some of yesterday's comments that we, from time to time, differ in views with ALPA with regard to the relevance weight given to the human performance in accidents, but we share their concern that we have to go further in identifying the underlying reasons of crew deviations.

We very often approach the scene of an accident and what at first glance looks like a very routine set of conditions, we have to determine why the crew deviated from their performance and why it ended up as an accident. We also recognize that the human factors aspect of our accident investigation is perhaps the most subjective. We find it very difficult to apply objective measures to the measure of fatigue and workload, so we're keenly interested in the

activities that are going on here to help us find that effort. We want these answers to help us better identify accident causes but even more we look to try to use these answers to help us reduce our workload.

In response to Dick Gabriel's comments, I would like to say that about a year and a half ago we started a very intensive effort to upgrade our accident data base, both from the human performance and the crashworthiness efforts. We looked to industry to help us do that and we reached out and tried to get input from the manufacturers and users. We hope to conclude that effort within the next year or so and provide industry with the kind of answers they need to do their job. We're always open to accepting inputs. We hope that you'll take advantage of that and tell us what you want to know to help look at crashworthiness and human performance studies.

I would also like to comment or reiterate a comment made early yesterday by the gentleman from ALPA that as I've listened to the presentation so far and look at those yet to come, it looks as though we could do more to emphasize the general aviation efforts in the human performance area. I hope that the FAA program will broaden to include those. Also there were some comments yesterday but they were fairly brief that touched the air traffic control interface, and we would hope that the program be expanded to include that.

So we're very encouraged by the effort. We want to lend our wholehearted support to its success. Thank you.

MR. LOWRY: Thank you. I don't think there was a question in there, so we'll accept the comments from NTSB with that.

MR. PORITZKY: S.E. Poritzky, FAA again. I would like to get you to talk a little bit about the second half of my earlier question.

MR. LOWRY: The full mission simulation and the simulation and the in-house, out-house --

MR. PORITZKY: Yes. Let me phrase the question. Specifically, I think I heard the group saying that we are a long way from fully validated objective workload measures. I also heard everybody say, we sure as hell need it, and, of course, that's the way we feel at FAA and that's the way you feel. I think that's the way everybody feels. The question now comes and I'm looking for free consultation help here. Of course, how do you best go about doing that?

Do you utilize universities? Do you utilize government laboratories, government simulators? Do you use the capabilities that you have in your plants? Do you use a combination and how do you see the interaction? And let me assume first, before everybody says it, yes, we're going to do it all together and we're going to talk to each other, given.

I want to ask a specific question though. Is the best place to do this, realizing that everybody will be in the act, is the best place to focus in your kind of laboratories, in government laboratories, whether they be NASA, FAA, DOT or is the best place to focus on these very, very tough fundamental questions in the universities, wherever they are?

MR. LOWRY: We'll try not to give you an all-of-the-above answer, but we'll just come down the panel and see where we come out, starting at the far end for a change. Dick Gabriel, could you pick up and then we'll walk it down this way.

MR. GABRIEL: I guess I'm not really sure. You are talking about research issues, say things that need to be -- You are not talking certification, anything of that nature, you're talking about basic fundamental research issues or applied research issues. That's a tough one in terms of knowing how to split it. You'd have to look at the question, the specific question. I know a gentleman from NYU who commented about the fact that the universities are doing some excellent basic research. I assume he's referring to some of the stuff that Chris Witkins and Danny Gopher and some of those guys are going in the crew workload type things that are -- not crew workload but the basic mental workload aspect of things many of us in the industry are aware of. I think that the one thing that they don't have is as intensive understanding of the operational situation perhaps as some of those people in the industry do.

They also suffer from a lack of realistic simulations. They do the simulation job, but it's a part task simulation job. I think that is going to be a problem for them. I think there are some obvious advantages they do have. They don't get hit with schedules and budgets and things of this nature quite as heavily as we perhaps do at times. So it would be difficult for me to give you a precise answer in terms of what I think the mix ought to be. I think it's going to depend upon the specific research issues, specific topics

we're trying to get at and in terms of that topic, deciding what's the best way to go.

We have had some good relationships with SRI on wind shear and things like that in the past where it has worked out very effectively. The manufacturer provides the simulation and the operational awareness and the SRI team had the primary function of designing the experiment and conducting the experiment and the final report; but we had a wack at that final report, so those kinds of team arrangements, I think, would work reasonably well, or at least they have in the past. I don't know what else I can add to that.

MR. LOWRY: Dick Heimbald, do you have a different view or response?

MR. HEIMBOLD: No, my view is quite the same, I think, since it's sort of uncharted territory. I suppose one thing that would be helpful is to have a subsequent smaller workshop, get interested parties in there and start communicating with one another. There's some sure things that can be done; for example, we have a study contract now with Boeing and Douglas and in that case, our man took all the human factors for a couple of weeks of flying with British Airways, did a lot of automated sort of flight testing. That is non-academic, but it gave the people with a more academic mind a chance to see what's going on in the real world. And I think probably those of us who have more practical objectives in life may not be -- maybe I'm speaking for myself -- aware enough of the latest thing that is going on the universities.

So I would like to see some more ad hoc sit down meetings where people talk things over and then when the question comes up of which facility is best to use for some agreed upon objective, I think those things should be thrown over to discussion then and people should just sort of show and tell what they have and kick it around and see what's best.

MR. LOWRY: Del, how would you respond?

MR. FADDEN: I think a balanced program is required. Initially, with most of those measures, you've got to deal with them in a reasonably abstract sense outside of the real environment in order to get enough understanding of what they really mean, to understand how it might possibly be applied. As you move out of that phase into trying to apply in more like the real environment with real design problems, then I think it's appropriate to move that

into industry, shared work where it starts out in academic community and it moves into industry as it gets near final validation in the sense of how it would be applied for real.

I would emphasize that the key reason why we support it is because it's going to reduce the time and effort involved on our part. We think we do an adequate job of this. We're not at all uncomfortable with it, but it takes a lot of time and money. Now, if we can use some of these objective measures to get answers a little faster, a little easier early in the design, fine. But they're never going to help us before we have equipment because, until we put the human being in the system and operate with him in it, the objective measures are no use. So we need the combination of the analytic measures as well as objective ones.

MR. PATZ: My name is Patz. I am a consultant human factors psychologist and pilot. Dick Gabriel made the statement this morning that says, give us something to shoot at. And that was something to tempt me beyond my limits here, so I'm sort of beyond the air again today; but I've seen the application of modern technology in airplanes.

All three of your teams up there have some impressive equipment, tri-color radar displays, push button displays, map displays, pretty nice stuff really. It must make you feel kind of bad when you read the newspaper and you see one of those elegant airplanes that you just made has splattered, and it's just made a big hole in the ground. And that's sort of where I come in because that's the sort of thing that I do. I don't look at it in the design stage, I sort of see the spare parts when they're laying around this big hole. I would like to talk about that for a second.

It seems like you're designing for convenience. You are bending all your efforts to apply modern technology into an elegant and very expensive flying machine.

If I were to accuse you of not designing for safety, all of you would stand up, including the hair on the back of your neck, because it's your concept that you really do that.

MR. LOWRY: You are right.

MR. PATZ: Okay. Well, what causes aircraft accidents? They can be lumped into various categories. There's certainly no single cause, but I'm

sure if you could, you have the motivation to design the accident potential out of the airplane.

Let's talk about a couple of accidents here. Let's talk about several accidents, and we'll go over them quickly. United Airlines -- we're not going to harp on the airlines here. I'm sorry I even mentioned it, but some crew climbed into a 727 in Chicago, forgot to put the takeoff flap down, fire-walled the airplane, takeoff warning horn went off, but they persisted and the airplane would not fly, rolled it up in a ball.

Another crew descending into Salt Lake City kept the descent rate too high too long, was unable to recover, hit the ground, broke the airplane apart, burned a lot of people up.

Some other people tried to fly out of Philadelphia, had an engine failure, tried to put it back on the ground because they didn't think it would fly, most of the people walked away from that one.

Somebody tried to land an Eastern Airlines -- Here I go again, I'm sorry. A 727 at JFK, got a downdraft, tried to recover, didn't make it; on and on and on. The first guy that bashes the 747, \$48,000,000 worth.

There's a guy over in Europe, didn't deploy the flaps for takeoff. He meant to but he didn't. There's some pilot error in here on all of these things. You build the airplane magnificently.

I fly Boeing airplanes, and my only word for them is superlative but other people fly Douglas airplanes and their comments are the same.

In the accident investigation business, there's a sort of critical incident technique, what is there that you can find about these accidents wherein you can get a handle on it? Also in the airline business, there is a nice device, it's called a simulator. And one of the things you can do with a simulator is freeze it. And what I want this panel to do right now is fly along with me in this 727 at JFK, and we have the airplane slowed down in landing configuration and we hit a big downdraft and the vertical air speed has started to increase, airplane comes off the glide slope, somebody says maximum power and we rotate it. And the airplane just keeps descending, and we're all going to be in a simulator now. We're going to go down and freeze it. This airplane, the tail pipe is six inches off the ground, one microsecond

from impact, and no one is going to live through it. And what I want to charge your panel with is, if I was a human factor practitioner, how could I help this crew out right now? That is a long ways from Seattle and Los Angeles in designing tricolor radar displays and map displays, all of which are nice to fly with but things we can live without. How would you like, just while you're frozen here, think a bit about what you could do for that crew at that moment? What could we put in that airplane or how could we train them to extract themselves from that situation and that lists -- I just quit because I don't want to take too much time -- neither was my list exhaustive but there are many many more situations.

While we're thinking about that thing then, Colonel Ettinger here was here the other day, and he flies an F16. And we're not going to change the subject, we're all talking about the same thing. But one of the things that he can do with his F16 is extract maximum performance out of it. He has to. That's the defense of the U.S.A. He wants to go hack down a MIG 25 Foxbat at 80,000 feet with his little F16. And it's going to take maximum performance to get it. Well, we don't fly fighters around, we fly airliners around. We're still frozen there, but I suggest to you that one of the things that three holer pilot wants right now out of that airplane is maximum performance; and if he doesn't get it, he's going to die and he's not alone in the airplane. There's about 100 people with him. I want you to visualize all those accidents that we have and imagine that all the people that were on board that airplane wouldn't fit in this auditorium and you probably couldn't fit them in this building. And if you tried to get all the airplanes back that have bashed in this manner, you probably couldn't fit them in all the gates at Logan Airport.

What is there that we can do to help this guy and how does that apply to Colonel Ettinger here?

There are some devices that can be engineered into the airplane that will help people extract maximum performance. We are just bug smasher drivers but every once in a while we have an application for a maximum performance and that's what we want and that's what you can give us. Boeing test pilots wish to test their airplanes -- I'm sorry, many apologies. Boeing and Lockheed and all the test pilots fly maximum performance because they want to certificate their airplane to the maximum of their ability. They want it to haul the

maximum weight off the ground. They want it to stop in the shortest distance. They want it to climb to the highest altitude. They want max performance. But when they're at the factory, they fly with an angle of attack indicator. I don't know how many people in here don't know what an angle of attack indicator is; but there's a curve of lift versus drag, what you want for max performance is the peak to be at the peak of L/D curve, maximum lift for drag.

All these test pilots, all these F16 pilots can extract maximum performance from the airplane, but we're carrying all these people all around without the device to permit us to do so. It's very costly.

In addition, I'm advised that the reason we don't have it is because nobody asked for it. When you say you talked to the pilots who fly the airplanes and you talked to the test pilots and you talked to these other people, I can't believe that the people that you talked to don't have this in mind. Now you may be talking to the wrong pilots, but I want you to consider it.

Okay, let's leave maximum performance for a second and we'll unfreeze these people because we were just unable to help them. You didn't put this stuff in the airplane for them when you could have.

When you take off, the next thing you want, if you have an engine failure, is how high do I have to climb this airplane to be over the obstacles for the power loss? I need to go no higher than I have to fly to clear the obstacles. How high is that? On a nice clear day, everyone knows I can look out the window. On a not so clear day, I'm faced with a problem. If you are taking off on Chicago's runway nine left, you are about to run through downtown if you don't stay right on the heading. What I suggest to you is that Colonel Ettinger's airplane has a terrain avoidance radar mode, terrain avoidance mode in his radar. Has anyone applied that to airline technology so that the pilot doesn't have to worry about obstruction clearance altitude? Okay, I'm sorry I took too long.

What I want to put to you is stay out of the factory when you are inventing the airplanes so much and read some of the NTSB blue cover reports as to why these airplanes crashed. I'm not saying they're all accurate. The ALPA said that sometimes the NTSB finishes the report before they're done. And I



wouldn't want to get into that discussion, but at a hearing, I can -- at an accident hearing, I can contain all the human factors practitioners there in my car and it only has three more seats. When you go to the factory, they're lined up and they have offices and secretaries and whatever. What I want you to do is change your location and see if you could help the guy that drives the airplane a little bit. Thank you.

MR. LOWRY: You have just frozen us all on a position here that we can't get out of because I was told this thing ends at 12:45 and we're there. I don't know if anybody wants to try a quick one. I think we heard a speech on angle of attack indicator and shouldn't we be looking at some reports and some mechanical things that we have in other areas? And I think the obvious answer is obvious, of course we should and of course we do. Does anybody want to cap it off for FAA or shall I -- yes. One more round.

MR. CLIFFORD: Doug Clifford, Boeing. I've been a little bit bothered by the question that is hanging in the air. As J.D. was with respect to altimeters, mine had to do with the apparent presumption that the new systems and the new models are a giant step forward. This will affect crew roles a great deal. And perhaps we could get a better insight in the question by asking the panel a couple of questions noting first that we've had inertial navigation in the airplanes for more than ten years and for about three years we have had performance management systems, performance status computers, they go under various names.

Imagine now an airplane with an inertial navigation system and its keyboard and display and performance management system and just described briefly how big a step it is from that in terms of the pilot as a computer operator, as a systems manager to the new airplanes. I think it's a very small one. My impression of it is that it is. So the two questions is how big a step is it really with the new flight management system displays within the change of the pilot roles and also, since we have so much experience with performance management systems and inertial navigators, how big is it a problem has it been as far as you guys know in terms of that being a hazard? I don't myself, hadn't noticed that there is much of a hazard.

MR. LOWRY: Doug, I think that has to be cut off too just because of the timing situation, no evil intent at all. To all of you, we certainly appreciate your attentiveness again.

#### SESSION 4

MR. ANDERSEN: Before we get started, John Enders, who is the President of Flight Safety Foundation would like to come up and make a quick announcement on some conferences on human factors that are coming up. OK, John.

MR. ENDERS: Thank you, Jim. I appreciate Walt Luffsey encouraging me to share with you two upcoming events of interest to the attendees at this workshop. The Flight Safety Foundation will sponsor their annual corporate aircraft safety seminar at the Brown Palace in Denver, Colorado on the 29th and 31st of March 1981 with the theme of human factors in corporate aviation. And the 34th annual international air safety seminar will be held November 8th to the 12th of 1981 at the Hotel Pierre Marquis in Acapulco. I thought that would get you. The theme is awareness, the key to safety and we will be soliciting papers from the international community dealing with human error and flight operations, air traffic control, training and maintenance. We support and encourage the kind of workshop activity we've been introduced to here; and I would say from the foundation's point of view, we encourage people to talk about the problems because there's obviously a lot of misunderstanding among the experts in the community, and it's only through forums like this that we can resolve these differences. Thank you.

MR. ANDERSEN: The last session, Operators' Perspectives on Human Factors is moderated by John Ralph, Senior Vice President Operations and Airports of ATA. All set John?

#### JOHN E. RALPH

Ladies and gentlemen, it's a great pleasure for us to be here. The airline business is very much a human factors oriented business. We have about a third of a million people on our payroll of whom about 36,000 are pilots. We operate approximately 2500 aircraft with 14,700 departures a day. So throughout the year, we carry in excess of three hundred million passengers. Clearly the need for error free human performance is apparent. We believe we've been fairly successful, always room for improvement. But to keep this in perspective, I think it's worth noting that it's safer to fly on our airplanes than it is to stay at home.

I would like to introduce the panel. They're sitting in the order in which they'll speak. Captain J.D. Smith is the Vice President of Flight Safety and Industry Affairs of United Airlines. J.D. will discuss United's employee assistance program. He'll present an overview of the effort to deal with the not so obvious human factors that pose problems that affect flying performance and safety.

Captain Ronald M. Sessa is Vice President of flying for U.S. Air. He'll make some comments covering flight crew resource management training. He'll highlight several important human factors issues that arise in daily operations and that need to be reflected in resource management training programs.

Captain Walter R. Brady is the Director of Flying Operations for Eastern Airlines. He will discuss the criteria for selection of new hire pilots and Eastern's experience with line oriented flight training.

Now Mr. William M. Russell, the Director of National Air Space Systems Engineering for Air Transport Association. Captain Gordon Witter, Manager of Flying Operation-Technical, American Airlines. Between them, they will discuss human factors and the changing role of the pilot brought on by the introduction of new technology.

Captain Jerry T. Fredrickson, the Director of Flying Operations for Northwest Airlines will give you a personal perspective on flight crew performance with some points about fatigue.

And finally, Dr. Robert C. Houston is the Director of Technical Training Support for American Airlines, and he will make some recommended comments on guidelines for human factors research which we hope the FAA and participants will appreciate.

Our presentation really presents a series of rather discrete snapshots of human factors issues of which these folks are intimately involved, so let's get on with our agenda. J.D.

#### J.D. SMITH

Thank you, John. And good afternoon ladies and gentlemen. For those of you that snickered about the flight safety foundation meeting being in Acapulco next year, it may come as a point of interest to learn that they just had one in New Zealand a couple of months ago so at least it's getting closer to home. I might point out it was very successful.

Now, the purpose of this human factors workshop is to identify and discuss current programs with an eye towards suggesting additional work or reduction of present efforts that should be effected to enhance the safety of the world aviation in the short and long term.

The ultimate objective of human factors activities is development of schemes which will assure good employee performance and an effective decision process among the numerous disciplines associated with design and manufacturer of the vehicle as well as those involved with operation and maintenance of the aircraft.

The greatest asset an organization has is its people. Without them, we have nothing. With this in mind, we wish to share with you a program designed to assist our personnel to accomplish safe and efficient job performance. Now we call it the employee assistance program. At the outset, description of this EAP program is not suggested for the regulatory process but rather as a sound management philosophy.

The EAP program is designed to assist employees to cope with what may be classified as real world problems; that if not resolved by the individual, could generate undesirable performance particularly as concerns the decision process. Assistance is available for alcoholism, family, physical, financial, chemical dependency and psychological problems to name a few. This is a jointly sponsored effort and is supported by management and employee representatives. And it is administered by our medical department. Each station has management and employee representatives who are available to help an individual understand the assistance available from the medical department. Such designees do not become involved in treatment of the person but primarily indicate where assistance is available and that help will be provided with dignity and privacy.

An alcohol rehabilitation program has been available for some 30 years. The scope of company assistance was expanded because of the clear indication that inability to cope with real world problems can adversely impact job performance. Qualified personnel are in place and outside assistance is available or necessary.

We first became aware of this potential challenge as a result of some discussion with Dr. Alcove of the U.S. Navy Safety Center some eight to nine

years ago. As part of the intensive investigation our people conducted that I referenced earlier this morning, we began to find some other support for the fact that these type conditions can have an adverse impact on our people. And as a result of some interviews and trying to determine causes, for example, of pilots have training difficulties via transition or recurrent, it became apparent that the type situations that I'm referencing here do have an impact, an adverse impact on their performance. And it is possible to come forth with some very corrective or effective corrective assistance and return the employee to good performance and in many cases preserve their employment.

The expanded assistance program has been in existence for more than a year. Our people advise there's clear evidence that employees are seeking assistance for reasons other than alcoholism. The EAP program does serve a useful purpose and is considered an effective prevention tool which can enhance job performance.

I would add the thought that if all the problems that have surfaced so far during this workshop were resolved, if we don't come to grips with the ones that we're presenting here, then we haven't been fully responsive to our challenges.

This workshop may be classified as a seed planting opportunity. Our seed is this; justification for an EAP program has been established and surely airline employees are not unique in being the only group requiring assistance in coping with real world problems. How confident are you that within your organization a preoccupied mind will not generate a poor or unsafe decision? Think about it and thank you.

MR. RALPH: Thank you J.D. Ron.

RONALD M. SESSA

Thank you, John. In addressing the subjects of the relationship of workload to error, minimum workload versus boredom, communications errors between pilots and controllers, command and control under stress and resource management training, the need and how to best address the problems, I'd like to provide some different perspectives of those subjects and also some different perspectives, maybe of the states of "being fatigued or tired" and how they relate to the end product, pilot performance.

Everyone here has been to a lot of these gatherings where we talk about pilot's fatigue, heard numerous definitions of what that means; so I guess one more won't hurt. I'll throw mine in. I think there should be a differentiation

between tired and fatigued. To me, tired means I don't want to do it and fatigue means I can't do it, if I'm truly fatigued. Something like -- I don't know how many watched the football game last night and watched poor Archie Manning get his brains beat out, I would say by the end of the game, he was tired. And if he had to play another quarter like that, he would be fatigued. And I know that this morning he would term himself fatigued and unable to go out there and do the job.

I guess in the real world what we are dealing with is the inbetween states. We are here to identify problem areas and establish future needs to deal with these problems, but I would like to identify what is occurring daily in the areas of my responsibilities anyhow and it's flight operations. And what we are doing to provide our customers with safe travel, not only today but tomorrow and how does an industry operate 14,700 departures a day with such an outstanding safety record? Surely our crews must be experiencing fatigue to varying degrees but the job still gets done.

Pilots in management are solving many of these problems on a daily basis together. Just as a few examples: you put together a schedule the best you can, you try to schedule them within the federal air regulations, within the guidelines and your pilot's working agreement. But it's computerized and that's not a perfect thing. Sometimes a trip comes out and it's not too good. On our airline, we try to run that through the base chief pilot and let him approve or disapprove the trip sequences; and where we find fault with one, we have them run it through again. But occasionally one slips through and it doesn't take long. If we start the schedule on the first of the month, by the third of the month we hear about the bad trips; so we look at them and see if there's a need for a change. If so, we make a change. Or there's the case of the pilot who is on an overnight with ample rest and the Shriners are in town -- not to pick on the Shriners, but they sometimes stay up late and have a good time and so he gets two hours sleep. Well, we pay that man to be intelligent and we found that he is. He calls up in the morning and says he doesn't feel so good, I can get the airplane to Pittsburg or wherever the crew base is. I would like to be relieved. Fine, we'll relieve you. These are just some simple examples, but we're solving the crew thing on a daily basis and that's how we survive on a day-to-day basis. We try and solve them as they come up.

The pilot who goes through a flying career without problems has had to master the adjustments necessary to keep this capacity level above the expected demands. He's managed to find a way to do that even without having been exposed to workshops and a lot of scientific reports relating to that.

And to go back to an example that someone used on a pilot that was raking leaves on a Saturday afternoon and was unable to get his nap and went out and flew during the night and was very tired. I guess he would be. I would expect that pilot if he had the same trip next Saturday not to rake the leaves. If he doesn't do that, then you have to wonder about his judgment. I think every pilot has a responsibility to show up to work 100 percent. If he has another avenue of interest, business, or whatever, it's his responsibility to allot his time so that when he reports to work to fly his trip, he's rested. We should start out on a full battery not one that is half drained.

To move on to the specific subjects, first relationship of workload to errors and minimum workloads to boredom. Again, I don't want to bore you with thousands of words that you already heard before on the subject.

Certainly high workload can be error producing but thousands of flights operate daily under high workload without incident. Why? Well, one reason is because the experienced pilot recognizes high workload periods before he gets to them. He prioritizes. He redistributes the workload in order to optimize his time and reduce the demand on his critical periods. He's aided by procedures, checklists, crew briefings, advanced plannings. He thinks ahead if he's a professional pilot. The pilot who doesn't do those things has got to rely on his overload capacity.

The subject of minimum overload versus boredom. I don't know, I think that's a much easier thing to deal with. That is one that we also address in our resource management training program. It's something that usually requires nothing more than a little imagination on some of the crew member's parts to keep things interesting in the cockpit over a long period of time when workload is low.

Communications error between pilots and the controllers? Sure, they happen every day. They're not always of a serious nature. Someone catches many of them but is that always due to a pilot being tired or a controller being fatigued or is it due to a fact that some people just don't have very

good communications technique? They don't practice good sound techniques on a daily basis and so when they are peered with someone else who doesn't practice them for whatever reason, the result is sometimes a miscommunication. It happens. There are times when adherence to established procedures goes a long way to taking you through the times when your attention is not always what it should be.

Command and control under stress. Well, we try to accomplish a little bit of that in the selection process. I think that most of us who work for airlines and know people for a long period of time that are employed by the airlines, by the time they approach the point in their careers where they become captains, I think most of managements have a pretty good feel for whether that pilot has the right stuff. He goes through training. You can't obviously check for all levels of stress. But I think we have a pretty fair feel for what the man can do as a captain. We rely very heavily in our airline as in most airlines do at check airman system. We try to choose the people on our airline who we consider the best pilots we have, not only from a proficiency point of view but from a point of view where they're respected as such by their peers. In that way, we feel that not only will they be in a good position to make judgments about whose going to make a good captain and who isn't beyond just what's required in the regulations but also be able to provide a little guidance and set an example.

The last subject is resource management. It's kind of new. We've been talking about it in the last year. Many airlines have started on programs. We started our own. We have had a few people in, some that we discarded because we didn't feel they related to pilots. And if you don't speak the pilot's language, it doesn't matter what you have to say he's not going to listen to you. We're concentrating in our program on the communicated skills so we don't have miscommunications not only between pilots and controllers but between crew members and not just the ones in the cockpit and the ones in the back, the ground personnel. It's important that if all resources available to today's airplane pilot to be utilized, he has to understand what they are and then be able to deal effectively with the people who are going to provide those resources. We try to direct all the thinking as the captain goes through this training towards the idea that he's doing it in an avenue of safety to prevent an accident. We highlight some accidents where we feel resource management



was a factor whether there was too much captain, not enough captain or no captain at all in the cockpit. I think it's an important issue.

Now many pilots on all airlines have been using these principles for years. They've never had problems with other crew members, ground personnel, controllers, nobody. They run a nice smooth flight. They don't have problems with airplanes. They report to work rested and give their passengers 100 percent of their available resources. The more of those people we can get the better off we are obviously. We don't need to help those people. They have been doing it through some innate knowledge already. We need to find out what it is that makes them do it that way without ever being taught and to help those and provide guidance for those who are good pilots but need to improve on those skills. And I think we have a good handle on that.

We are constantly striving to improve our selection and testing methods in order that we can better identify that kind of a pilot, the guy or girl, self-discipline, self-motivated and adaptable. I don't think that is an impossible task.

I think the future success in human factor development lies to a great extent in selecting pilots with the right stuff.

Before I conclude, I just would like to use an example of what I'm talking about. Our number one pilot on the seniority list has been through the whole spectrum. There's not many in the business who can say that. He flew the air-mail pickup extension, and he retires next year from 727-200. I've flown with him. I have been trained by him. I have given him proficiency checks over the years. Since I have been involved in training, he has been hijacked. He has been in three and a half G one and a half negative G air. He has been through the whole gambit of things that you would expect a seasoned airline pilot to have been through at one time or another. There's just never been a problem with the way this man has conducted his flights. He never has problems with the personnel, doesn't have problems with operating his machine. I think that if people are going to devote a lot of time and energy to research, I think what you should be doing is telling us how to find another guy like that. Thank you.

MR. RALPH: Thank you Ron. Walt, are you going to tell us how to get that guy?

WALTER R. BRADY

Good afternoon ladies and gentlemen. The human factors engineers have identified for us, at least five methods of improving human performance. These methods are: improved human factors engineering, improved training programs, improved crew procedures, improved motivation of personnel and improved pilot selection criteria and procedures.

I'd like to dwell on the last one, flight crew selection criteria and selection procedures. First, some observations about the changing role of the pilot. I'm sure we're all aware of the ever-changing role of the commercial pilot down through the years. And we know the role is still changing.

Remember when commercial aviation was young? The pilots were flying in open cockpits, carrying the mail and occasionally a few passengers. The aviator of that day was, he was considered to be a bold type character, fearless and brave. But by today's measurements, we'd consider him to be a "free spirit", unwilling to be tied down by some of our conventions. Probably his life-style and personality fit him well for handling the equipment and the problems of that era. However, the same descriptive terms surely don't describe the ideal commercial pilot of today.

Today's complex environment requires a very different type of crew man. In fact, there are some similarities between today's airline flight crew and a team of professional athletes. Both teams perform with the skill and the coordination of a well-maintained machine. They both require long hours of coaching, practice and study; but there, the similarity ends.

If we deliberately mix the membership of two opposing football teams, for example, the coordination will fall off abruptly. When these same professional men try to do their thing, they are performing with unaccustomed teammates. However, do the same thing with an airline crew and we still have generally the efficient, well-coordinated team performing the duties with skill and efficiency.

Crewmember interchangeability dictates that we select our pilots carefully and standardize principles and procedures to assure compatibility of efforts in our cockpits. When you consider the many different personalities that are merged daily to make up our flight crews, the validity of our pilot selection and training efforts soon becomes evident.

Whenever pilot selection is discussed, someone will usually quote the well-worn phrase, "We're not selecting pilots, we're selecting future captains."

Yes, indeed the times have changed. The responsibilities have increased enormously. Today we have a multi-million dollar aircraft, tons and tons of valuable cargo, lives of sizeable groups of passengers and they're all entrusted to the skills and the judgment, the entire personal resources of the man sitting in the captain's seat. The long move toward the assumption of such responsibilities starts with the hiring of persons possessing very special backgrounds and individual qualifications.

At this point, let me pose a question. If someone were to ask you what you consider the single most important attribute of a pilot, what would your answer be? Now my question is predicated on pilots or captains or commanders, if you prefer, being fully qualified and possessing whatever level of experience that you believe is desirable. Some of you might answer: leadership, emotional stability, others might say reasonability. Perhaps someone might come up with the ability to plan ahead or even the ability to act favorably under severe stress. These are all very good. And if we had the time, it might be interesting to see how you would rank them one, two, three, etc.

In our screening of new pilot applicants, we are looking for all of the attributes that I just mentioned plus quite a few more. We look for evidence of flying motivation. By this, we mean an actual devotion to flying. Now in the past some carriers -- and I might include our own, maybe we're looking for the president and chairman of the board in the pilot ranks. Primarily, we're looking for pilots, men that want to fly, that have an identification with the career of flying. They have to show a high interest in knowledge concerning aviation and aviation-related subjects.

We are also looking for evidence of a multi-channel information processing capacity. By this we mean the ability to concentrate in the presence of distractions, to divide attention and to shift channels without impairment of accuracy.

We look for sensitivity to others, that important attribute, empathy, awareness of and the insight into the feelings of associates and skill in dealing with subordinates in stressful situations. We're also looking for maturity, adaptability, dedication, self-discipline, decisionmaking ability, initiative,

self-confidence, tenacity, honesty and sincerity and, of course, bottom line, judgment. So we go on-and-on about the importance of these personality traits, but let's take a look at the several stages of the selection process that we use at Eastern.

The prospective pilot sends us an application, first step. Upon receiving the form, we look to see if this applicant meets our minimum standards, to see if he is an above average candidate and if he has attributes that distinguish him from others.

After screening the formal applications for the better candidates, we then ask some of those to come to Miami.

Now in the second stage of the process, the candidate reports to the personnel offices and he receives a mini physical examination, also followed by a series of ability and personality tests, and this takes a good part, the better part of half to three quarters of the day.

The next stage really consists of credential checks. In this, the third stage, the surviving candidates now interview with a member of the personnel department, one who has a special assignment where he handles pilot applicants only. It's a rather extensive interview in which the personnel officer looks at the "whole man". He's attempting to get an authentic profile that includes the good and the bad, the positive and the negative.

Then the candidate meets with the senior captain for a flight operations interview. Now we're getting into the guts of the guy, whether we want him to be a pilot on our airline. And after this he is exposed to a ride in a simulator, a DC-9 simulator. And the purpose of this is simply to evaluate his skills and general airmanship. As an interesting side light, there have been occasions in the past when we may have doubted the integrity of a candidate's logbook entry. Quite often the simulator ride made the difference.

Following day, the candidate goes through a major physical. And after this, he finally meets with either the Director of Flying Operations or the Director of Flight Training for another lengthy interview. Then he returns home and waits to hear from us good or bad.

The final stage, of course, involves going over all the results of the interviewing and testing and making a honest attempt to select people for

employment who are matched in terms of interests and aptitudes.

We realize only too well that there are several factors that appear to make careful selections more important than ever. One, increased job stability. Fewer people are ever discharged from the job than ever before. Two, higher training expense. An increasing amount of money has to be invested in pilots before they are qualified. The training time can be minimized if only persons with the appropriate aptitudes are selected. Three, the increased complexity of systems has made the effect of any error potentially more costly.

Looking only at the training expense, United Airlines has estimated that a mistake in pilot selection could cost upwards of \$250,000 over a 30-year pilot career. Good decisions in pilot selection will really pay off in terms of training requirements, whether we are discussing flying skills, resource management skills or a composite of all of the attributes that go into the making up of an outstanding employee and ultimately an outstanding captain.

What would we change if we had it to do all over again? We haven't had much chance to answer that question yet. The people doing the major interviewing on our airline and the testing seem well-satisfied with the procedures we are using. Progress through flight training by these particular candidates seems to be proving that our selection process has been thorough. So only time will tell. Perhaps we should be asking others the same kind of a question, how would you change your selection procedures and what are you doing that we are not doing?

So now that we got this gentleman hired and down the line we get into an interesting subject which we call LOFT, L-O-F-T. So I'd like to discuss Line Oriented Flight Training (LOFT for short). It's not a new concept to most of you but perhaps we can look at it during this session for its contribution in the area of human factors training and then ask the question: What can we do to increase its value in this area?

The environment in which we operate continues to become more demanding of management skills on the part of the pilot conducting the flight. This is directly related to the complexity of an operation intended to attain absolute safety while conducting all-weather flying. We recognize the need to shift some of the emphasis from training for manipulative skills to something closer to management skills.

LOFT is not a new idea. We did not invent it, however, we used a similar format at Eastern in the late 1950's on our DC-8 and our Boeing 720 series aircraft. At that time, of course, the simulators available had no motion, no visual capability. As a result, we were unable until recently to develop the training environment that would simulate the real world with acceptable fidelity. We needed to illustrate the value of standard operating procedures as they affect the line pilot in everyday operation.

The advent of simulators with motion plus the visual system ability to reproduce a realistic airport scene, provided us with the tools we needed to construct a worthwhile line oriented flight training program.

Currently, we have two LOFT programs in operation both approved by the Federal Aviation Agency. One is for the Boeing 727, the others for the Douglas DC-9. LOFT programs for our 1011 and the A300 are under development. We expect to have them on line by the end of this year, 1980.

Our present program consists of six scenarios per aircraft type. Each one contains three legs. The scenarios are designed to fit within the four-hour time frame ordinarily used for a training period.

When we develop our programs, we emphasize strict realism. All the legs are flown in real time. The problems presented for the crews to solve are those which can and in many cases have happened in real aircraft.

So let's look at a typical training session and perhaps we can then better identify where the human factors and resource management training fits in.

The training period begins with the full crew attending for the examination of the flight departure papers. At Eastern Airlines, all of those flight departure papers are stored; that is, the dispatch release, flight plan, fuel requirements, weather sequence, forecasts, etc. are all in the computer and are recalled as each crew requires them prior to their departure. Since we strive for considerable realism in the LOFT program, we also have flight departure papers stored for our training flights. They're recalled by the instructor prior to briefing his crew.

As in normal operations, the crew now examines the papers for minimum equipment items, fuel requirements, notices to airmen, etc. They also check the appropriate weather sequences, forecasts, make a determination of the fuel and perform any other preparation that the Captain deems advisable.

When the Captain decides that sufficient time has been spent on briefing, the crew proceeds to the simulator. While in the simulator, the Instructor/Check Airman, he may be one or the other, he links normal communications among the start crew, ground control, tower, departure control, company and so forth. He does not under any circumstance interfere with the normal operation or functioning of the crew while they're in the LOFT concept.

Once under way, the crew must solve all the problems according to their own best judgment. We took great care to avoid overloading the system. Had we cluttered it with unrealistic situations, we feel we may have induced mismanagement. But any of the errors, crew mistakes or errors in judgment or ignorance of procedures will remain until they're corrected or until the aircraft is on the ground. The training requirement is for four hours and all the legs need not be completely flown.

A word about scripting is appropriate at this time. All our sequences are tightly scripted and deviations and additions are not permitted except that items may be deleted if there is not enough time in the four-hour period left to perform the rest of the maneuvers. As a timing aid to the instructor who is conducting the scenario, we designed the last leg with an adjustable time frame. The script is so written that the instructor has the option of selecting a point during that last period which a problem may be inserted or taken out so he'll get the best utilization of that last leg. When the simulator period ends, the Check Airman leads the crew's debriefing session.

In the time since Eastern Air Lines began the LOFT program, we have come to see it as the training vehicle of the future. We believe that LOFT can provide more realistic initial training because from the first day of training we can emphasize the kinds of skills needed to operate a particular aircraft in today's complex environment. We believe that LOFT develops considerable judgment skills and provides excellent experience in structuring priorities. It also illustrates the consequences of poor resource management, ignorance of proper procedures and lack of command presence.

Training conducted in simulation very closely matching the environment in which the crew normally operates gives a crew the best opportunity to see the normal and abnormal situations and their solutions. For example, in the simulator, a Category II approach to a runway closely approximates what the pilot will see in the real world. But in a training aircraft, as soon as you "pop

the hood," of course we don't do too much of that anymore in the airlines but as soon as you "pop the hood," the pilot usually found himself in an entirely visual environment. So LOFT provides considerably more realism.

In addition to its value as a training vehicle, a line oriented training program is an excellent evaluation exercise. The simulator's ability to accurately reproduce the line pilot's normal working environment plus the instructor's briefing prior to the start of the period, emphasizes to the crew that they are expected to perform in a manner exactly as they would perform in the real world. This permits us to see a more exact picture of how the crew functions in areas as decision-making, cockpit discipline, the Captain's command presence, crew coordination and other resource management skills. The crew is also briefed that the LOFT program is not constructed as a fail or pass check ride; it's rather an evaluation of their skills to uncover in what areas, if any, they may need some additional training. We feel that this is important to remove any threat of embarrassment or punitive action. By so doing, also, we diminish the tendency of the crew to respond in the way that they think the Check Airman wants them to respond and apply instead their own best solutions to the situation. We believe that this environment produces a very clear picture of the capabilities of the crew being evaluated.

We have found LOFT to be excellent for remedial training. We have taken crews off the line who have had a problem of one kind or another, put them in a LOFT training format to duplicate the problem or the circumstances they experienced, let them pinpoint the moment or a point in time when they thought things had gone wrong. We can sometimes show them what they did, what they should have done, maybe demonstrate a better way to do it the next time.

As a result of our success with this approach in remedial training, we are now experimenting with the construction of modules to be stored in the computer. Each one will be fabricated to illustrate a particular problem or abnormality that, if mishandled, could have serious consequences.

When we get a crew requiring remedial work, for whatever the reason, we retrieve these modules from the computer, examine them and extract the problem. When linked will result in a LOFT scenario for that particular problem. Eventually, we hope to have enough modules to cover all the difficulties that we see on the line. In this fashion,



we will tailor a training program almost exactly to fit the kind of training that we feel is required.

We also intend to use LOFT to evaluate our current operational procedures for both normal and abnormal situations and help us to determine needs for and the effectiveness of any new procedures. I think this is vital to our operation.

We intend to further use LOFT to spot any trends indicating weak spots in our training programs.

When all of our simulators are approved for the landing maneuver, LOFT will make it possible to complete all phases of training in the simulators. We want the training programs that will assure competency in the area of manipulative and management skills prior to the pilot's assignment to the line. The line operating experience will serve to validate the effectiveness of the training program, quality control if you will.

To sum up, Line Oriented Flight Training as it has been developed at Eastern Airlines, represents the best training vehicle we have seen thus far. We believe it matches all of our training needs more than anything yet devised. We shall, of course, use LOFT programs in training for the annual and semi-annual proficiency checks. Soon we will turn to it initial training. We see it as a marvelous device for the remedial training as well. As a tool for developing new procedures, we have really found it to be unequalled. We are very confident at Eastern that LOFT will lead us to zero aircraft time.

So in closing let me just throw out this challenge: What more can be done with LOFT to enhance its usefulness in training for human factors and resource management skills? And could the LOFT concept be used in other areas of the overall aviation system?

I appreciate having the time to have talked to you. Thank you.

MR RALPH: Thank you, Walt. Bill Russell will be next.

WILLIAM M. RUSSELL

The human element is a major consideration in airline management efforts to make proper judgments and decisions regarding cockpit system changes which could result in changes in pilot roles. I recognize that there are many viewpoints among us in this auditorium that can constructively contribute to future

human factors efforts. Let us keep in mind that it's worthwhile to take stock in the current situation and consider steps to create future programs that build upon our current methodology which has been so successful.

Today when significant cockpit changes are proposed, they are considered by the airlines individually or in cooperation with other airlines or both. The Airlines Flight Systems Integration Committee is one mechanism by which views can be exchanged and, where appropriate, joint action undertaken. This committee was originally formed in the early sixties as the All Weather Operations Committee. The revised name stemmed from an increasing scope of responsibilities; nevertheless, the expanded all weather operations continues as a major item of committee activity.

Both available information on fundamental human factors characteristics and that gained from practical experience are considered in conjunction with system changes.

Let me offer some examples of factors that airlines considered with system changes currently taking place and those recently completed.

One of the most recent changes in the cockpit is the advent of the flight management and performance data computer systems with their promise of improved fuel efficiency. While minor improvements have been identified relating to the primary characteristics of the aircraft - that's the current aircraft I'm referring to -, the fundamental concern has been focused on getting the information for a particular flight in a useable form, in a timely manner so that it is actually used to conserve fuel. Thus, the advent of these airborne computer systems which were designed to provide information in a timely way. However, a number of airline management pilots reported to the Flight Systems Integration Committee that while this improved information was used initially, a significant percentage of the flight crews did not apply the information throughout every flight. This nullified the advantages of the equipment. While the workload during the period was relatively low, most carriers recognized the human characteristics and decided that in order to obtain the long term benefits, flight management/performance management computers had to be coupled to the aircraft controls. When this capability was provided, a much greater use was obtained from the equipment, as pilots perceived that the system was aiding them in accomplishing their job with reduced workload. While this did not solve the question of potentially insufficient workload during

some flight phases, it did achieve human acceptance.

Another example of airline consideration of human factors has been in the implementation of the ground proximity warning equipment. While this concept was a subject of much debate, once the decision was made to implement the airlines addressed those human issues which might preclude its effectiveness. One of the "loudest" issues was the audio level of the warning. Individual airlines expended a great deal of effort to find an audio level which would be acceptable in the cockpit and permit the equipment to perform and still meet the FAA requirements. Joint effort was undertaken through the committee to control exposure to nuisance warnings through obtaining revised ATC procedures and cockpit knowledge. The lessons learned from ground proximity warning equipment continue to form an important cornerstone for the work on improved warning systems.

Cathode ray tube displays is another area where human characteristics have been considered. Recognizing that varying operating conditions resulted in varying needs for flight instrumentation, the airlines have pursued the implementation of CRT displays for a number of years. Following successful demonstration of the concept of CRT flight displays in simulators and aircraft, the committee recommended that CRT displays be provided on the instrument panels of the next generation of airline aircrafts so that such displays could form the basis for evolutionary growth. Color displays were recommended, not only to avoid losing the color capability of conventional instruments but in order to tap a new dimension of human sensory capability permitting flexible growth of the display. Evolutionary symbology was emphasized, as many airlines recognized the need for the human pilot to transition to the advanced instruments from conventional instruments and in some cases a multiple transition; that is from conventional to advanced back to conventional and again to advanced was anticipated. It was believed that humans can more readily accommodate changes if the new technology has a number of elements in common with the old. The airlines asked that the new displays initially utilize symbologies similar to conventional instruments. Those of you who have seen the displays for the new Boeing aircraft will recognize a number of evolutionary characteristics. I had hoped that Del Fadden this morning would show more of the displays but even in this map display he showed, he described a number of characteristics which were similar to the present day instruments.

The foregoing discussion is not to detract from Boeing and Collins development accomplishments but rather to point out that the airlines are actively involved in making decisions which affect the pilot role, and in doing so recognize human characteristics and limitations. When looking toward the future, one can expect that this level of concern will continue or increase unless, of course, the choices are foreclosed by political or regulatory action, events which we would consider most unfortunate.

In considering future system changes, it would be desirable to make the best practical use of human and physical resources. Where new functions are placed in the cockpit, means to constrain peak workload also is to be considered. Maintaining minimum activity level would also appear appropriate to offset potential boredom effects.

What kinds of efforts are needed to provide a proper base for these future decisions? In addition to efforts to improve the overall level of knowledge of fundamental human characteristics, efforts appear to be needed to gain more knowledge of human reactions to automatically generated warnings and alerts and where significant role changes are contemplated, validation of the human ability to perform the new role. We must not ignore the need to perform other functions in the cockpit and major changes cannot be considered in isolation. In this area, flight simulation can be an important tool (validated in flight as appropriate).

The ATA committee and others have discussed the question of human reaction to warning systems. While FAA, Boeing and SAE-7 are working on cockpit alert and warning systems, I think all of you recognize this as an area of concern when one examines the present number of bells, buzzers and clackers in the cockpit of today's aircraft. In considering such systems, little fundamental information appears available to indicate the conditions under which a pilot will respond to an emergency command system immediately upon recognition of the command. Similarly, there is little information to confirm that provision of background information will aid the reaction under real emergency conditions or whether it leads to a series of questions by the pilot which results in a greater overall delay. Probably there is an intermediate solution. In my view, information on fundamental human characteristics in event of such warnings should be explored further. The existence of any significant numbers of nuisance warnings has been recognized as a basic problem to achiev-

ing timely reactions to warnings also. But hereto, little fundamental information is available on the human mechanisms involved, the maximum levels and frequency of nuisance warnings which can be tolerated in the aircraft cockpit and the extent to which this is affected by the means used to present the warnings and communication -- to the flight crew would appear to need to be further evaluated.

Considering the broader question of human interaction in communication with computers and well not addressed to all aviation are rather -- well, not addressed to aviation, a number of organizations have been looking at innovative approaches such as computer voice recognition, even considering keyboard entry; it may be possible to make significant improvements for aviation, and we heard this morning some discussion of voice recognition even in aviation. I believe that was in the contents of military development program.

Better tools are also needed to facilitate work on aviation human factors questions. The NASA development of an oculometer is a significant step forward and further refinement would appear desirable. In addition, more information is needed on its limitations. As mentioned earlier, full crew simulation performs an important role and improved oculometers should be adapted to use in these simulations.

Before completing my discussion, let me mention that there is a need to explore the extent and impact of the potential use of flight path angle information on CRT displays on the flight instrument panel. After all such information can be displayed head down and is not solely the province of head up displays. The reason for mentioning this is that use of flight path angle appears to involve different human assessments and reactions than used in conventional approaches. More insight on these assessments and reactions would be useful.

In summary, consideration of human characteristics and limitations has and will continue to be included in airline decisions on cockpit system changes. Some additional practical human factors research would appear useful to provide a better basis for future decisions affecting the pilot role in the system.

Thank you.

MR. RALPH: Thank you, Bill. Captain Witter.

GORDON WITTER

Thank you, John. Ladies and gentlemen, I apologize for my scratchy nasally voice. I'm recovering from something of a cold. Thanks to our outstanding environmental systems on our modern day airplane, I -- rather my ears survived the trip to Boston Sunday evening, however, this morning on the way down from the 23rd floor of the Sheraton, they both blocked. If I'm talking too quietly or too loudly, please let me know.

My comments will be brief. In considering one aspect of the changing role of the pilot in this age of increased automation, considerable thought has been given and has been referred to here frequently today and yesterday to the problem of pilot work overload and/or pilot work underload. Is the job of flying from Point A to Point B becoming easier or is it becoming more difficult? Is the increased automation providing the pilot with less perhaps too little to do or perhaps the increased or rather the task of programming the relatively new computerized systems an additional task to which we have to prepare ourselves? Would that in fact in itself be a burden on the already busy flight crew? While discussion on this subject will no doubt go on for some time to come, I think it's agreed at this point that there are at least certain phases of flight where computerized automation is making a task of the pilot easier if not considerably more precise. No where is this more true than in the approach and landing phase of the minimal visibility landing. I would pause here to emphasize that so far as I know, nothing has been developed nor does anyone anticipate the development of a system better equipped to make real time decisions in a flying situation than the experienced pilot. But provided we do a good job of keeping the pilot in the loop with real time information, today's automatic landing systems can and have proven to be more consistently accurate than manual control in very low visibility landings. This over the years has been something of an adjustment.

In considering the subject of the changing role of the pilot, think of this: We have reached the point relatively recently where a pilot will, in fact does, make the decision on whether or not to continue his approach to a landing without clearly seeing the touch down zone. In this context, the so called blind landing although we are not there, is certainly staring us in

the face, and we have to develop procedures to prepare ourselves for it. And I might add, prepare the crews for this eventuality.

The development of sufficiently precise and redundant equipment, the training and the instilling of confidence in the equipment and the procedures developed to accomplish this, to reach this point are significant. It is a significant achievement that we have come as far as we have. Perhaps even more significant is the fact that we have changed or are in the process of changing the role of the pilot in this environment from one who has previously and hopefully from time to time still does, see to land the airplane to one who monitors flight instruments and automatic landing system heads down to touch down. This is our situation today in Category 3A.

Category 3A is defined as operations with no decision height to and along the runway with external reference during the landing phase, during the final phase of the landing with a runway visual range of not less than 700 feet. That is Category 3A and we're there today. To refer to such an operation as a blind landing, of course, is very incorrect. However, the determination whether or not to continue an approach to a landing in this very restricted environment is made necessarily heads down because the external visual cues are insufficient upon which to base a decision, land or not to land or have the potential of being.

Additionally, Categories 3B and C down line are presuming the absence of external visual cues; therefore, the development procedures and the training for Category 3A, it seems to me, it follows should be those to be employed for Category B and C hence head down.

In reaching this point, we determined some time ago that when landing and conditions, weather conditions of less than Category 1, less than a 200 foot ceiling and less than something under a half mile visibility, we would unburden the Captain by coupling the airplane to the autopilot and procedurally requiring the First Officer to fly the airplane through the autopilot down to a decision height.

The decision height being that limit to which a pilot may descend before deciding to continue the approach to a landing by means of visual cues.

The Captain in this monitoring role unloaded, relieved of the actual flying of the aircraft is, in our opinion, in an excellent position to make a

decision when he reaches decision height. This procedure has worked well for us down to the Category 2 minima of 100 feet above the terrain and a forward visibility, a runway visual range of 1200 feet. Below this point, below 100 feet and below a forward visibility of 1200 feet, the determination to land or not to land are based on the Captain's assessment of the external visual cues become extremely difficult if not downright impossible. At a decision height 100 feet above this terrain, you have somewhere between 5, 7, 8 seconds between that 100 foot point and touch down. The decision making process in this environment difficult as it is, is complicated by potential perceptual errors made all the greater by the restricted visibility. While many of you are familiar with these perceptual errors, potential perceptual errors, let me hit them one time quickly for you. The shorter time a cue is available, referring back to the time I mentioned, you have from decision height of 100 feet touch down, 5 to 8 seconds. The shorter time a cue is available, the more apt you are to misperceive that cue. The less clear the cue is, the more likely it will be misperceived. Cues which are similar to others are likely to be misperceived. Situational changes, roll rates of less than two degrees per second per second, acceleration, deceleration may not be perceived. There are sensory limitations to dark and light adaptation, near and far adaptation. The angle sensing capability of man is very limited. His distance and altitude estimation is very poor. Continuing background cues, rain, blowing snow may cause misperception. The more limited the view by whatever, the more less likely there will be -- the more likely there will be perceptual errors. Experience does not seem to be a help here. Bright objects always seem closer. Big broad objects always seem closer than little narrow ones. Cues that a pilot does not expect to see, for which he is not set, are likely to be misperceived. In discussions of this sort, it's about this time that the question of head up display comes up, and I'll go ahead and bring it up.

The people I work for and I personally encourage the continued development of head up display systems, their potential use a VFR slot orientation and slot stabilization, black hole approaches, low visual cue, departures and as a transitional instrument from instrument meteorological conditions to visual meteorological conditions in Category 1 and 2, flying conditions where external visual cues to land the airplane are required is great.



It's our present thinking, however, its use in the Category 3 environment is limited, that the head down philosophy better applies itself to the complete Category 3 system by no external visual cues.

In summary, external visual cues in the Category 3 environment are not sufficient upon which to base the landing decision. Category 3A is just a beginning but believe me, we're getting there and the completed landing without external visual cues and routine air carrier operations is close at hand, just around the corner. Our challenge, I think, is to move very slowly, methodically and to properly prepare the pilot for the necessary modification in his role, the change in the information he uses to determine whether to land or whether to go around.

Thank you.

MR. RALPH: Thank you, Gordon. We have two presenters and it's approaching the three o'clock break. I think it's probably more fair to your human factor's needs for us to take the break a little early and we'll have our last two presenters after the break.

(Coffee break taken.)

(Session 4 continued.)

MR. RALPH: We have two presenters to go. The first in our series is Captain Jerry Fredrickson who will give you a personal perspective on flight crew performance and with some particular emphasis on fatigue factors. Jerry.

JERRY T. FREDRICKSON

I've been asked to discuss the crew fatigue workload and stress factor and aviation from a management viewpoint and also to briefly discuss the NASA Ames meeting in August on the pilot's fatigue and circadian rhythm upset or desynchronosis whichever you wish to call it. And I have done a great deal of reading and studying on the subject lately and discovered after four years in the business, I really don't know all I thought I knew about the subject. But I did enjoy one of the remarks by the NASA report, Dr. Lauburse's description of stress and he said that stress is when your wife, a stewardess and the mortgage are all overdue at the same time. Not bad. But many of the problems that we're faced with have been discussed already in the meeting and perhaps a minute or two on the subject of circadian rhythm upset or sleep disturbance

and the body rhythm disruption as it affects the airline flight crew is worthwhile.

The problem is well known to long distance jet travelers, certainly known to pilots particularly those who fly routes that are long and nonstop. To the traveling public, it's known as jet lag. To the airline pilot, it's known as a pain in the ass. It's common knowledge among pilots that rapid transition from time zone to time zone creates a lot of problems and pilots find they can't sleep. They find themselves faced with decision making tasks when their bodies and their minds are still in the night phase and they're performing at a lower level of proficiency. Pilots who fly for airlines who fly strictly north and south routes are very fortunate. One Captain said if God intended man to fly east and west, he would have made the equator run north and south.

We know the major cause of fatigue among long distance flight crews is sleep disturbance and the inability to sleep, which is linked with desynchronization of the normal body rhythms. And the problems have been widely examined, and it's been studied. There is very little progress in finding a solution and it's also clear that tolerance to the problem varies widely with the individual. Some people are free runners, they hit the ground running when they get to wherever it is they're going and seem to have no problem with it. For others, it's almost intolerable. There may not be a total solution to the problem and it may be something that aviation has to live with and work out. Some pilots solve the problems for themselves by bidding out of the system. If they can't tolerate that type of an operation, they go back to a domestic operation; for example, rather than fly a Chicago/Tokyo non-stop, they'll go back to their home base and fly Chicago to New York and let it go at that. That may be the best solution of all for those individuals who are intolerant of the problem. I don't think there is any general acceptance in the industry that crew performance is significantly affected by this type of fatigue, at least to the point where flight safety becomes a factor, but we certainly recognize the problem.

NASA conducted a workshop, pilot fatigue in circadian desynchronization or rhythm upset during the month of August this year, which I had the privilege of attending. The workshop participants represented the scientific community, the military community and the commercial aviation world including pilots and management. And there was general agreement on the issues. There was

some major differences on the severity of the problem, and it couldn't be clearly defined what the extent of the reduction and pilot capacity or ability to perform was.

Well, some of us have had a lot of experience in the field, 40 years for me to be exact. We've developed or discovered some of the answers the hard way by experience. And I would like to go over briefly some of the steps the airlines have taken to ease the problem and some may not seem so important, but when we put them all together, they make a significant contribution to solving a problem. Pilots understand, for example, that when you purchase a sixty million dollar airplane, which is at least what a 747 costs, now, that you just can't fly it from eight o'clock in the morning to four o'clock in the afternoon. That would be nice, but the economics of airline life wouldn't allow that and the pilots realize that. So first of all, we've attempted to improve our scheduling as Ron mentioned and this takes a lot of cooperation between the pilot group and the management and yes, as Ron Sessa says, we do slip up on occasion. We usually hear about it from the pilot.

We try to monitor the schedules as carefully as we can looking at the circadian rhythm problem.

In the old days, long distance flights took a lot of preparation, took an hour and a half to two hours to draw up the maps, look at the weather, check out the Loran and all the rest of the equipment that was necessary for overwater navigation. And I think with the advent of INS and computer flight planning, we've taken a great step forward in reducing the pilot workload prior to the time he gets in the airplane. We used to get on the airplane sometimes this tired before we ever started. So with the advent of the computer and INS navigational system, a lot of that workload has been relieved. I think we have better weather forecasting today and better weather reporting, which eliminates a lot of the anxieties that the pilot has; and it also eliminates some of the surprises which none of us want in the aviatinal business.

We try to provide rest facilities on board our airplanes where the situation demands. Our 747-200's are long range 747's, for example, which require multiple crews, for example, a Chicago/Tokyo non-stop flight, which is 13 hours and 20 minutes. We have spent a great deal of money and given a lot of thought to the building in and designing of rest facilities for the pilot on board the

airplane. We have an isolated compartment on the upper deck on the 747. It has beds, place to hang your clothes, individual air outlets, individual reading lights, blackout curtains, sound proofing to isolate the resting crew member from the noises in the cabin and so on. We've even gone so far as to separate pilot meals and trying to provide them with what medical experts at the meal clinic tell us is a nutritional value for the pilots.

I think any responsible company will examine and very carefully select pilots rest facilities at the layover, and we do that. We try and provide our crews with quiet rooms and hotels, rooms that are temperature controlled, that have blackout curtains to create an environment that induces sleep. We try to provide the separate and rapid transportation to and from the airport to minimize the travel time spent in route again to minimize pilot's fatigue. We work with customs departments in the various countries to get the crews through customs as quickly as possible again to reduce pilot's fatigue. And we make certain when the pilot returns from his trip, no matter how long it is, five days, ten days, whatever, that they allow an adequate recovery time after the completion of the trip. And we figure roughly that the pilot flies a trip, goes through ten time zones, he needs a minimum of five days after returning home to get himself back to normal.

When we get an airplane from the factory, the factory provides us with the basic data package, the performance package. They also provide us with a basic operational manual. We refine and redefine the procedures, tailor them to the operation which suits our particular airline. And this may be the most important aspect or factor of all in offsetting the effects of pilot fatigue.

We spend an awful lot of time and put a lot of thought into the development of our operating procedures. We try to design the procedures so that the pilots equally share the workload. We try to make the task as short as possible, the shorter the task, the less vulnerable it is to error. We are very careful in the sharing of the task assignment so that no crew member is overloaded.

We try to prevent boredom on long distance flights by assigning tasks that are of some interest to the pilots and that is a problem on long distance flights. There is no question about that. When you're sitting there with a 747 strapped to your fanny for 10, 11 or 12 hours, boredom is something that

has to be considered. But there are a lot of items that you can challenge the pilot with and cannot overload but keep him busy. And fuel consumption would be one of the items that is considered there, keeping careful track of the fuel that's burning and flying the airplane at the right speed and the right altitude in order to conserve as much fuel as possible and believe me this interests pilots.

And we pay particular attention to critical affairs of the flight, take-off and the approach and the landing. Let me give you an example of what I mean by that. A very high percentage of the accidents that occur in commercial aviation take place after approach landing phase of flight, so by careful planning and design and the use of checklists, we teach our crews to get all the work done that can possibly be done before beginning final phase of the approach. And I'm sure that those of you actively associated in aviation are familiar with the stabilized approach concept. That has many values. If all of the work that has to be done is accomplished prior to the time the pilot gets to the vicinity of the outer marker, about the last five miles of the approach, there is nothing left for the pilot who is flying the airplane to do except fly it. There is nothing left to do for the other one or two crew members, whatever the case may be, except to monitor the approach. And we pay for this on airlines in terms of the fuel that is consumed. Yes, we like to delay extension of the flaps, fly the airplane at a clean configuration for a longer period of time. It would be a hell of a lot cheaper, but the price of safety is and presently the way we operate to me is well worth it.

Speaking of distractions on final approach, I think we need some help from the FAA here, specifically ATC. It was interesting to me to note that in one of the NASA quarterly reports, it was mentioned that one of the biggest distracters in the aviation system is ATC. Yes, communications are necessary but sometimes I have the feeling that the controller was vaccinated with a phonograph needle the day he was born and hasn't stopped talking since. One thing we don't need is a lot of irrelevant conversation in the cockpit during an ILS approach down to bare minimums to 1200 RVR. And yes, we have pilots that talk too much, too. They have the same problem and we have some silver tongued orators that we have to discourage once in a while, don't use the PA system when you are taxiing, going across active runways. You are in the process of receiving an ATC clearance, stay off the PA system during the

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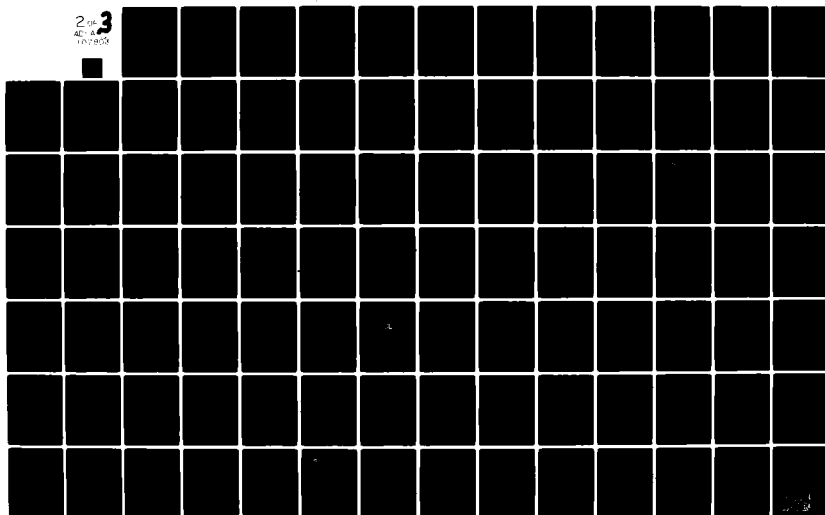
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initial phases of the takeoff and certainly during the approach and landing. In other words, pay attention to the job at hand. So for those of you who are not in the aviation community, if you don't hear anything from the pilot on the PA when you think you should, that might be a good thing.

And then the final thought on pilot fatigue. The experienced pilot develops his own defense mechanisms; for example, no matter where he is, he may try to have dinner at six o'clock and at ten o'clock he tries to go to bed. This is very difficult, sometimes it's impossible. It's hard to sleep when everyone else is up and about, and it's hard to sit in a hotel room all night, you can't find a restaurant opened to get something to eat and so on in Tokyo because it's day time in your own time. It's interesting to watch how the experienced pilot handles the problem of fatigue. They slow things down and that's good and it's a normal reaction; for example, you watch someone who's tired, he realizes the fact that he's tired. The flaps go down sooner, the gear goes down sooner, the airplane is stabilized and the approach configuration on speed, on the glide speed and so on is a little bit earlier than normal. The pilot doesn't want any surprises, so it's a normal reaction, I think, whichever thinking an experienced airline pilot uses to help solve the problem of fatigue. So flight crews are aware of the fact that trying to carry out daytime tasks during the body night is a difficult thing. And we certainly want them to be aware of it and to understand the phenomenon of circadian rhythm upset in order that they can apply whatever protected measures that they can to eliminate the potential risks that are associated with the problem.

In summary, I think the circadian rhythm problem has been identified and confirmed. The relief of the problem still eludes us to some degree, there is no question about that. But I believe NASA workshop last August was very helpful and that their further studies and work continued. I think we can look forward to some added progress in solving the problem. I've been asked to give a personal perspective on flight crew performance based on the 40 some years, almost 40 years in the business. Airline travel is now our safest mode of transportation, has been pointed out before. I think that speaks for itself. And it's true that pilots have more help than ever before. It's certainly true they're not winging it alone as they used to do in the old days. But the saying that the buck stops here still is certainly appropriate when it's applied to the cockpit to these airliners. Let me give you an example of pilot reac-

tions to a problem, which is very interesting and it's also very conclusive as far as I'm concerned. One of the airlines biggest problems today is the price of fuel. Since 1973, we watched the price of fuel climb and climb and climb with no end in sight. Our budget used to be four and a half, five percent of it went to fuel. During the month of August, the budget on the Northwest Airlines, over 60 percent of the direct operating cost went for fuel. Forty-eight percent of our total operating budget was spent to buy fuel. And how the pilot's reacted to this and what have they done to help us? Since the advent of the fuel crisis in 1973 with the cooperation of the pilot group, we reduced the fuel consumption on our 727-100 fleet 11.96 percent; on our 727-200 fleet, 7.79 percent; on our DC-10's, 4.42 percent; on our 747 fleet, 3.67 percent. We have done this in all capital expenditure, the installation of a computer system aboard the airplane and so on. The total savings are 33 million gallons of fuel a year, roughly thirty-three million dollars. We've done it by optimizing climb speeds, optimizing cruise altitudes, lowering cruise speeds, lowering descent speeds, reducing the APU usage, reducing the operating weights of airplanes where possible. We reduced the fuel loads that are carried. We've improved the engine bleed air management, reduced fuel tank ring. We are now using every dispatch procedures in the long distance flight to reduce fuel loads and computer flight plannings with the increased accuracy that's associated with that.

But finally and most important of all is the pilot's education and increased awareness and effort on the part of flight crews to conserve fuel; and the results achieved to me are very impressive, and they certainly make a significant contribution to the economic well being of the airlines. And I think in an age that has been described by many as one that is characterized by self-concern for -- it's refreshing to observe the concrete results of the effort that the pilots have put forth. And to me, the pilot's response and performance has been nothing shorter than magnificent. I believe, Walt, that you'll find the pilot and the airline response through the ATA to the problems discussed at this meeting will be just as good. And we're anxious and willing to make a contribution not as adversaries but as the concerned co-workers in the industry that is very dear to all of us.

MR. RALPH: Thank you, Jerry. Dr. Robert Houston will be our last presenter.



DR. ROBERT HOUSTON

Thank you, John, and ladies and gentlemen. We've had general endorsement and agreement of the large role as human factors research can play in our field. There have been some very specific and strong endorsements of the necessity for human factors research, and there have been some mention as to how this should be conducted, and I would like to get a little more specific in the remaining few minutes this afternoon.

Now administration of research in the area of human factors is at best a difficult job. And as a matter of fact, it may be one of the most difficult or some say the most difficult area in which to conduct research. Our discussions these two days has made it very clear that we're dealing with highly complex difficult, defined areas. There has also been direct and indirect expressions of concern about how this research will be conducted and the qualifications of those who might conduct it. There have been references to the need for determining what we already know or discriminating between conflicting information and whether other results can find their way into actual use and most pessimistically whether funds will even be available. And this has not come out stated as such, but I have heard the statement, "Let's keep this away from the human factors' people." Well, maybe some of you are sitting out there thinking that, so I would like to address some of the issues in hopes that this research program that the FAA would like to embark on will avoid some of the complications and the problems that, in some cases, have created bad impressions.

Now all of what we have said the last couple of days and concerns expressed, some of them implied and some explicit, add up to the fact that research standards must be exceptionally high and must be carefully directed to the right problems and well-administered.

Certainly there must be control of research to ensure that it is systematic and this was brought out earlier that we should take the systems approach, but this control must be exercised without suppression of new approaches. There isn't any magic formula for this, but here's where a highly experienced advisory group and administrator are essential.

Research must have practical application but should not be limited to an immediate application only and a point was made this morning about the develop-

ment of a theory on which we can operate so there will be application to a broad area. Now I think that's very essential. We'll never catch up if we don't develop principles that have broad application.

Unfortunately, I frequently heard the excuse for not applying results that the research, previous research was conducted under slightly different circumstances and consequently doesn't apply to the current situation. Well, that's a valid concern that research conducted previously is applicable and care must be exercised to avoid expense and delay of repeating research that is perhaps unnecessary just as it should be, care should be exercised to use research results that really aren't applicable to the situation.

It has been mentioned that a handbook for research results specifically for human factors in aviation might be of help in this area. There are some handbooks or some books that could be considered handbooks presently. They do have their limitations, however. But certainly we need to apply what we already know and there is a lot of information that is presently known that we could apply if we gave it enough emphasis and if we really understood some of the research.

Some of the research shortcomings include the fact that there is no apparent application or meaning to the potential users. Now it's possible that the fault lies with the presentation of the research results, but it's also possible that the research itself was faulty, the design was improper or the goals were unrealistic in time and capability or perhaps simply the result of inexperience in the research area. More about the report of the results in a few minutes.

Another possible shortcoming is that the research results can be misleading because of insufficient experimental control or inappropriate sample of subjects or inadequate research tools or facilities or equipment, so we have to make sure that the results or the research is conducted in a proper manner so that the results would not tend to be misleading but rather direct us in the proper way.

It's also claimed sometimes that research is too costly. Well, conducting research, as you all very well know, human factors area in aviation is not a cheap process. On the other hand, I think we have to be careful and make sure that we don't use a complex simulator, when perhaps a simpler research situa-

tion would do just as well. Sometimes a research shouldn't be conducted at all. There may be ample evidence that would provide the answers without having to spend the money on the research, but this is certainly an area of concern that the money appropriated which may be of short supply will be used in the most effective manner.

Now when research results are faulty, the tendency is to blame the researcher or the research organization. Well, this may be correct but I submit that frequently it's the fault of the rather than the researcher or research agency, it's the fault of the research administration for not providing proper guidance or support or complete information and then more about that in a minute. But we can't expect all research to be fruitful and no research program will be 100 percent effective. If we knew which was going to be productive research, if we knew what the answers were going to be, we wouldn't have to conduct the research. But the objective is to make the research as effective as possible, and it's my position that the research administrators should be held responsible for the record achieved. I think there's certain incentives there. Well, I don't have any magic answers, and I don't know of anyone who has magic answers for fully effective conduct of research programs; but I have some guidelines that I would like to suggest as a result of my personal experience and observations of lots of research over the years.

My experience has been in actual conducted research, it's been in administering research contracts, and I was glad that Dick Gabriel mentioned that Army/Navy instrument program. I was there on active duty as a Naval Aviator when that research program was started. That was one of my first experiences with administering research. I've also been on the other end. I've been a principle investigator and, of course, I've been in the position of using research results for many years.

Some research is excellent, high quality, really classic. Some of it is very good and not presented very well and admittedly some of the research, from my point of view at least, doesn't seem to have much value. So the question is, how can we present the problems and how can the FAA or other administering agencies get the most money for their dollar and provide us in the field of aviation with the information that is really going to help us in all the problem areas that we mentioned in the last couple of days? Well, this was mentioned this morning. There must be a highly competent experienced oversight or advisory group.

Ron Lowry mentioned that there must be the highest level of management and this research area is more difficult. It's very important to every one of us here. Consequently, it must be guided in the most competent manner. There must be, the competency must be both in the human factors area and in the technical areas involved so that this advisory group can give direction to the research. There have been several indications of what direction research should take. I think basically it comes down to the advisory group and their competence and their experience and their ability to direct the research in the manner that will make it most useful and most efficient.

Now this advisory group shouldn't just make some initial recommendations; but from my experience, it's more important for the advisory group to have a continuing function and to review the research plans and the implementations and spend enough time to ensure that the research is, in fact, being carried out to accomplish the guidelines that have been set up and this means you can't be a rubber stamp group and the people involved must be available to spend a reasonable amount of time in order to do this job properly. It's not a deal of a once a year, half a day meeting, it would be a much more of a commitment than that.

The second vital ingredient is an administrator and staff, if necessary, highly experienced in human factors research. This individual, the administrator, who will make the day-to-day decisions that will have a major impact on the effectiveness of the research or program; and I visualize that this administrator and staff if appropriate would open the doors for the researchers, system translating results and their role would be a continuing one not just letting a contract and a year or two years later asking for a report. And recall that the administrator, in my view, should be responsible for the effectiveness of the programs so he should have a day-to-day involvement and not to interfere with the conduct of the research or second guess the researcher but to give the advice and guidance that his experience is appropriate for.

And, of course, the next guideline, it seems to be an obvious one and that's a careful selection of the research agency or contractor or who ever is going to do the research. It's not always the case that there is that careful selection. The personnel involved in conducting the research and their supervisor should be qualified to conduct the research, the best qualified that is possible to find and a list of the staff members who are going to work on the

project is not simply enough. It's vital to know who is really going to do this research and what kind of direction is that person or are those people going to have.

Another aspect is, there must be continuity in research. In this complex area, it's not possible to award a contract here for a year and there for another year and expect to have really effective results. There must be a continuity of effort to build up the personnel and the facilities that are necessary for doing research in this complex area. That means then that research contracts should be long term and that is all the more reason for careful selection of the research agency to begin with.

Another area that is very difficult, I know, I always found this as a personal problem is that timeline should be established and support provided in a realistic fashion. The timeline should not be unrealistically short for the research to be done. On the other hand, there should be reasonable goals so there is incentive for the research group to get the job done as expeditiously as possible. And, of course, another seemingly obvious statement; this contract should be awarded when the criteria met for the selection of the researcher; but I've heard and tell on occasion there are contracts awarded to take advantage or commit funds that are going to be lost at the end of the fiscal year and I realize why this is done but it's a temptation that I think should be definitely avoided.

I had some discussion this morning about the balance of the research and I would just like to echo the statements that were made that there's room for research potential and universities and government agencies, consultants depending upon their qualifications and the nature of the problem. I would hope that there would be a reasonable balance in the research that will be conducted.

Another area that was mentioned this morning in connection with the development of instrumentation systems is the necessity for very close coordination with the users, and this applies to research as well. Now I've seen this done very effectively recently and it's a critical area that I can't overemphasize too much. There is a research problem. There's obviously a using agency and there must be close liaison with that potential using agency to make sure that the research is properly designed, the analysis is a meaningful one and that the reports prepared are going to say something to the proposed using

agency. Now this is a means of commitment on the part of the using agency whether it's the FAA, the airlines, the manufacturer, the union that they provide interested and sympathetic technical personnel to provide the necessary technical input. They must put aside their biases and vested interests as best they can and provide the guidance that their technical expertise justifies. On such guidance requires a sufficient commitment of time to ensure proper consideration of research, design and the variables to be considered and the methods of evaluation, etc. This is something that takes a significant amount of time. Again it's not just an hour meeting some afternoon with the researchers but requires a series of meetings and considerable amount of time if the technical guidance is really going to be adequate and sufficient.

Now the research group has a responsibility for the final decisions. There is no question about that. And that should never be lost sight of, but they make the final decision after careful consultation with those who are technically expert. Now you can carry this too far, of course, and consult and coordinate so much that you never get anything started and never get anything done, but I don't think that's the danger at this point. The using, proposed using agency should also assist in providing access to proper experimental subjects and facilities as appropriate. I think this is a responsibility that should be taken very seriously. And then in addition to that, the proposed using agency should work with the researcher in the preparation of the report to ensure it's written in a language that would be understood by the users.

Now this raises a question of someone trying to influence their results of the research. I think with competent researchers, they would not permit this to be done. The advantage is that the report will be written in a manner that will be understood by those who might use the results and consequently much more likely to be applied and much less likely to be misunderstood. I think this is really a vital aspect of the whole research program.

Now, of course, results must be evaluated realistically and from a point of view of operational significance. There may be statistical significance in differences in the research results, but the question needs to be asked, "Are these differences of operational significance"? Some cases there are no differences which could be the result of a task that isn't sufficiently challenging or difficulty with establishing measures of performance. Proper design in a pretest of the research minimizes this kind of a situation.

And I might just add in parenthetically that one of my first jobs as a new PHD pilot was to develop objective measures of pilot proficiency and that was about 30 years ago. Research has continued in this area all this time, and I think the statements that were made this morning are very appropriate and Del Fadden indicated that properly devised subjective measure can be very effective.

And my conclusions from first participating in that research and observing it all these years is that you can measure components of the highly complex pilot's task or controller's task or what have you but to get a truly objective measure of the whole task is a very difficult job and it was also pointed out this morning, could very well be misleading. I don't think the researcher would be held up because we had difficulty in measuring performance. We need to be conscious of the fact that we have to measure it in some way or another but certainly not embark on a major research program to try and develop objective measures of research, objective measures of performance and hold up on the research for that reason.

Then there is a question of economic justification, evaluating research results, and I haven't mentioned that up to this point and I don't think that should be mentioned or considered until the results of the research are in. Certainly we can't ignore the fact that the economic implications and someone has to make the decision whether the costs involved are justified by the potential gains. But it's a factor that has to be considered, and I think that this is the appropriate time for consideration.

Finally the research organization should have a responsibility in addition to preparing the final written report. There should be at least one and possibly series of oral presentations to explain the results of the using agency or agencies. Again I have seen this done recently very effectively, and I think it should be part of any research contract. This would have two helpful effects. It would force attention of the contents of the report which otherwise might just sit in somebody's file or on top of a desk as ashamed to admit, frequently happens on my desk. So it forces attention of the contents and also be a powerful incentive to people conducting the research to prepare the results in a manner that would be understandable to the potential users of the results and in a manner that would be meaningful to them. So I think then this would be an important aspect, important part of any research contract or research agreement.

This has just been a brief summary. This is an abbreviated list of research guidelines.

In summary, we've all agreed that there is a real requirement for human factors research implicitly or explicitly that such research should be well conducted. I can't overemphasize the importance of the very, very highest level of guidance for this research program. As we have said, it's a highly complex area. It could go off in all sorts of directions. It's going to take some expert guidance to make sure that it heads off in the right direction.

We, the ATA, I think you gathered are enthusiastic about this potential. We hope that the research program will proceed with every great expedition and that the results will be helpful to us in the many problem areas that have been pointed out in our two days of meetings.

Thank you very much.

MR. RALPH: Thank you, Bob. And we're prepared to respond to your questions now.



### QUESTION AND ANSWER SESSION

MR. BEARD: Thank you, John. I'm Craig Beard from the FAA, and I think quite often when we get into discussion on human factors consideration, there seems to be a strong tendency to concentrate our interests or we develop a strong preoccupation when concentrating our interests in the cockpit design and human factor aspects working with the pilot.

I think that there are other considerations that really haven't been adequately addressed at the Conference where human error has a potential for bringing down the aircraft; and I guess I'm really addressing airworthiness area.

I know one of the discussions I had with one of our leading aviation journalists about nine months ago in one of our more frustrating periods, I just casually commented that I was a little bit puzzled that we could have a major wipe-out accident; and when it's related to airworthiness, it seems to turn all our worlds upside down, we get dropped on our heads. There's endless hearings, endless articles in the news medium, but if it seems that the accident is more operational in nature, in a few weeks time the public seems to be content with just leaving it alone.

He called me back a few days later and he said he thought he had the answer. He felt that the general public and maybe some of our politicians felt that if it were a human error that they could readily identify, them being human themselves, they could identify with that and they could excuse it; but when it's the equipment that has failed, that they can't excuse. And I think we ought to realize that just about every airworthiness failure can be traced back to some sort of a human shortcoming in the handling of that equipment, either in the design or in the maintenance itself.

We have had one or two speakers that have casually touched on this subject. I believe the gentlemen from Douglas mentioned an awareness to do a little better job in writing maintenance manuals. J.D. Smith mentioned a program that would certainly have positive benefits in influencing the attitude of our airworthiness airmen in the way they go about their work.

There has been a little bit of discussion about airborne systems that will help us more accurately address the failure to be corrected in maintenance, but I guess in the form of some rhetorical questions, rather than looking for direct answers here.

What is industry doing? Is the manufacturing industry and the operating industry working together to seriously catalog the kinds of maintenance glichers that we can reasonably expect in service realizing our aircraft are maintained by human beings? Putting this in such a way that we are developing design guides for our designers to be used industry-wide to either prevent these kind of errors or minimize their impact.

Is there anything going on in the operational side of the industry when you have -- after you design a maintenance task to be performed and when you're developing your work cards and the step-by-step procedures to be followed, looking for opportunities for maintenance glichers?

In assessing the impact on this, we in the certification area, failure mode and effect analysis are quite common. Do we have anything going on that you might call it a screw-up opportunity and effect analysis where there's cooperation between the operating industry and the manufacturing industry to minimize these opportunities or minimize effects of these opportunities. I think these are a number of questions that we need to address, not to play down the crew workload, not to play down the importance of cockpit design, but also not to forget that there is another technical area that has a direct impact on the safety of aircraft and human factor consideration, very important part. Thank you.

MR. RALPH: Okay, thank you. I think if I were a European, I would call that an intervention instead of a question. Does anyone from the panel care to elaborate? I think the concern is in terms of having a cooperative program between the manufacturer and the user so that deficiencies can be fed back into the design process. Is that a fair representation?

MR. SMITH: Well, I hear your comments, Craig. It takes me back to the reason I was up here the last time which had to do with basically communicating data and figuring out its effectiveness. In our case, and I'm sure we're not unique, we have a maintenance conference call throughout the system every day at 11:30 Chicago time and one of the prime reasons is that problem defini-

tion process and the events that occur that would be of interest to the manufacturers and others are discussed there, and the feedback to the manufacturers.

We've got three principal inspectors in our maintenance facility in San Francisco who are communicated with on a routine basis back and forth. And without dragging the thing out, I think we're back to the point that the information is transmitted but what's done with it after it's received in a different quarter? And everything I see indicates that there is a pretty effective line of communication.

MR. RALPH: Any other members of the panel care to respond? Ron Lowry, would you care to respond or have any of the manufacturing reps that still might be here also comment?

MR. FADDEN: Del Fadden, Boeing. Let me just comment briefly, we get the data that you send and that the other carriers send in to us. It goes into an experienced retention and analysis group whose job is to look through it for patterns, not only within an airline but across airlines, and then get that data to the designers working the systems involved, whether it's a specific or if it has broader implications to the designers of new equipment or our research groups. So the information is transmitted within our company to a variety of different places and a follow-up occurs to see that it was understood. Very frequently what we do is go back to the airline or airlines. It may result in having a symposium in Seattle, talking about it, bring the airlines in to discuss the problem so that we thoroughly understand or us going out there or them coming to see us. It depends on the nature of the problem, but I think, as you point out that the communication link is there, and it's used reasonably well.

MR. RALPH: Thank you. Do we have another question?

MR. PARSONS: H.M. Parsons, Human Resources Research Organization. I would like to comment and amplify on what Bob Houston said. My experience in human factors engineering goes back perhaps as far as his to the '50s at Douglas Aircraft, so coming to this gallery has filled me with all kinds of nostalgia and also with the realization passed along to you that there have been two other efforts in the last two years to increase the capability of a large domain with respect to human factors. One, of course, is the nuclear power industry. The other is the Air Force. The name of the game in both of these

efforts has been professionalization, and I think that's another term to add to what you said, Bob.

Now, what does professionalization and human factors mean in a domain such as civil aviation? Well, I think it means the same as it has meant in nuclear power and in the Air Force, and you probably are familiar with the efforts being made in the nuclear power industry to improve its human factor capability since the Three Mile Island. You may not be as familiar with the study that was conducted, which I led recently, for the Air Force in attempting to upgrade its human factors engineering capability. In both cases, it's meant getting more and better professionals from the human factors field into the domain so there is a qualitative as well as quantitative requirements, manufacturers people, researchers and practitioners are probably distributed in the normal curves so, like in most disciplines, so you will have some poor ones and some very good ones. And the aim is to get the best you can out of the potential supply.

Another technique, of course, with respect to professionalization, is education. We recommended that the Air Force Institute have a number of professional educational programs at the graduate level in order to create a supply of human factors people, both in uniform and, particularly in uniform, but also for civilians.

Another requirement is that the coverage should consider not just R and D or research but applications. In the Air Force instance, this has meant the system program offices in addition to the laboratories. I don't know what the applicability of this consideration is to FAA because I don't know a great deal about what their operations are, and obviously their needs will differ from the needs of the Air Force or of the nuclear power industry.

Incidentally, with respect to nuclear power, the problem of professionalization is a very difficult one because there was nobody in it earlier on who could build very much. But EPRI, the Electric Power Research Institute, has stepped into the gap and the interim measure to fund through various organizations various kinds of improvements for nuclear power plants. And meanwhile, the Nuclear Regulatory Commission is building up its own in-house capability and that's one way to proceed, is to have a build-up plan and start it out with short-term operations as quickly as possible and have long-term plans.

In the Air Force project, our recommendations were to have a plan of a 10-to-12 year period because the build-up in-house has to be progressive. You can't accomplish a cold human factors capability overnight of a professional nature.

Getting back to the applications area, we consider that the operational commands, the logistics commands and the test centers and those parts of the systems command that dealt with ground systems had been the most neglected locations for human factors work, particularly in the applications area and to some degree in the research area. And there may be an echo here of those same considerations for ground systems in view of the comments made about maintenance, the needs, for example, that perhaps exist in ground systems, operational systems like air traffic control in civil aviation. So although there is no distinct parallel between FAA and their needs and what the Air Force has needed and what the nuclear power industries needed, there are perhaps some lessons to be gained from those vocations and those current efforts.

MR. RALPH: Thank you. I think that perspective, based upon your experience in those two cases, would be well served for the FAA.

I had a question here on this side of the auditorium. I would like to take him next and then over here, please.

MR. ORLADY: I'm Harry Orlady, recently retired airline pilot. I didn't make Jerry's 40 years but I did make 39 of them, learned to fly, oh, about a little over 42 years ago.

And this is in response to Walt Brady's question of other ways to use the LOFT simulator training program, and I certainly share his enthusiasm for it. I think it has tremendous potential as a system research tool, and I would suggest considering using it in this fashion.

One thing that is a fact in this business is that every single airline pilot goes through the simulator training twice a year. It's almost virtually the only time that the total population whose performance that you are concerned is available. I think that we could learn a great deal about the operations of this very critical element in the system, and I think this is quite different from examining their individual performance. This is the way the population reacts and something very, very close to the real world.

I think it's, I believe, although I'm not certain, but I believe it would be asking too much of the people who are involved in the training and checking and those procedures to do this sort of thing because you would be looking for a completely different thing. And I think you could learn considerably about the ways by definition acceptable, qualified crews react, where they have their problems. If the people who are doing this were involved in the research, and I would certainly support all of the qualifications that Bob Houston made in it, you could learn considerably more about the way the system works. You could learn considerably more about ways it could be improved. I think you could learn considerably more about effective training, and you could go on for a long, long time. There's several other things, but the essential part of it is that you aren't looking at people who are volunteers for some kind of a project. You are looking at really the relevant population. I don't think it would cost a lot of money in some term, cost a fair amount like almost everything does, but you could have almost no additional cost for the industry because people are doing this all that time anyhow. And I think that I really truly believe it has a tremendous potential. Simulators have always had it. They haven't always been used, I think, to their optimum research capability, but the inclusion of LOFT puts, just gives them a considerably greater potential than at least, I think, they have ever had.

MR. RALPH: Walt, do you have any response?

MR. BRADY: As far as a system research tool, I can maybe comment on something somewhat a little bit of levity, I guess. We had a procedure early in the game where we introduced a pilot incapacitation, Captain incapacitation, and it was very early in the program. And we knew that our first officers, or we assumed that they had been properly prepared for this sort of a thing. And I can remember the first few days after we turned this loose in the LOFT program, talk about the system reaction. Before that thing was two hours old in Miami, the procedure was already being talked about out in Seattle. The Captain had been removed from the simulator and all of a sudden, the first officer was up there and it was not his check. And the airport that he had planned on going to was below limits, and he was given a pressurization problem in flight and all of a sudden here he was, alone with this ball of wax; so that as far as the distribution of the information, something like this unfolded very early in our program and even though it happened to one crew, one team the first time,

the system became aware. And just in that area alone, it has improved the awareness of what's going on. Thank you, Harry.

MR. RALPH: We had a question on the right.

MR. MILLER: Miller, System Safety. I want to tag on to Mr. Parsons's comment. I think it might very well have application here.

First, I should explain that I spent six months with a Nuclear Regulatory Commission in the aftermath of Three Mile Island. I was retained specifically to aid on this particular area among a couple of others and what shocked me was that there were at least three very significant human factors evaluations of nuclear power plants that got no attention whatsoever at least one of those forecasts quite accurately what happened at Three Mile Island. When I evaluated this in terms of the entire Nuclear Regulatory Commission activity, I saw something which, quite frankly, I think I also saw in the FAA and NTSB to bring it into aviation and that is -- and I don't mean to be derogatory towards the leaders of these organizations, but they literally didn't know what human factors meant nor did the senior people in their agency know what human factors meant. It's not an easy thing to understand, even among the people who profess in it.

There's many different variations of the definition of it. And I guess what I'm suggesting here is that if the gentleman in the FAA or the NTSB or any other group that is concerned with this problem, if you have a reason to believe that your bosses don't understand what the discipline is about, then they better be indoctrinated in it or you're going to waste a lot of time. I would draw the comparison, if I may, with the difficulties we've had over the past 20 or 30 years to -- I use the term advisedly, a safety discipline. Until we got in the military to the commanding officers, until we got to the presidents of the airlines or the presidents of the manufacturers, sometimes through the courts, until we got to those senior people to understand what the discipline was about, it didn't get the support within the organization.

MR. RALPH: I think those are very sound words. Having spent some time in uniform myself, I know very well what the commander doesn't support doesn't get done. We have a question in the rear.

SPEAKER FROM THE FLOOR: I don't have a question, but I have a good lead in to comment that I want to make. It relates to the human factors program itself. I guess when I came here I had some ideas of what this was going to be all about, but I think of what I've heard so far, I would like to pass on my perception.

Number one, in the human factors, I can divide it into my own mind into two elements that I've seen that have been addressed here. One has to do with human performance and the other has to do with human behavior. And I would say that, from what I've heard, I would estimate that our dealings here, things we've been talking about, have been about 90 or 95 percent dealing with human performance. How to better interact to displays, instrumentations, locations, things related to the human machine, human instrumentation, interface and procedures, checklist and so forth. In other words, dealing primarily with how to fly or maneuver the machine much more precisely rather than dealing with that cockpit human behavior relating to decisions that have to be made.

If we look back at our accidents and our incidents and relate to human performance versus human behavior in the cockpit, it's hard to relate a 747 flying from Houston to JFK diverting to Newark and having three engines flame out because of lack of fuel. I don't think, from a human performance viewpoint, that any way we can relate to the accident in Mexico City or with three pilots in the cockpit going into Pensacola Bay. There's something related, I think. The ALPA members yesterday had a very good point. There is something else that's going on here. Why do these kinds of things take place? What is it in the human behavior in that cockpit that results in the incidents and accidents that we don't understand?

As far as human performance is concerned, every year we have probably at least one and sometimes two airplanes that, regardless of how much time we put on the performance and precision in which we fly, wind up landing at the wrong airport.

As far as performance is concerned, they probably do a pretty good job putting a big airplane in a little teensy airport. But as far as human behavior is concerned, why they do that, I think that's what we need to understand. Thank you.



MR. RALPH: Thank you very much. Did I miss someone over on the right? Okay.

MR. WASSON: Ray Wasson from Lockheed. I've heard members of the panel articulate some concerns about the changing role of the pilot, the effects of fatigue and stress and the importance of interpersonal skills as well as cockpit management skills and also the advent of new cockpits and new systems. Obviously, all these things could probably greatly benefit from the human factors input; and as a result, I would like to ask each of the people that represent a major organization how many human factors people do you actively employ?

MR. SMITH: I'm not sure I can answer the question because I have never been satisfied with the realistic definition of human factors. If I had my way, I would get rid of that goddamn term once and for all.

We do have qualified personnel to deal with interpersonal problems and many of the others that I mentioned earlier this afternoon, primarily within the medical department. There also some in the personnel department. I would kind of put them in the same category as the term human factors, but there are a lot of people that have the experience and background that is capable of responding to many of the points here, particularly in our training department.

We have a vast training function within United Airlines and composed of very highly competent people that know how to effectively communicate. That is probably not answering your question, but I wouldn't even know how to set up a job description for this so-called horrible term human factors.

MR. SESSA: I have to echo what J.D. said. I think we have an awful lot of expertise in our own houses. Many of you from the scientific community may not agree with that, but people who average in our Check Airmen ranks anywhere from 10 to 15 years of flight training of an airplane and simulator and observing people under all forms of stress, have a pretty sound background on how to communicate with them and what their problems are. For those who also participated in accident investigations, I feel they also possess a great deal of expertise in this area. There are some areas where they can be -- that knowledge can be supplemented and that's where we have to go outside.

At the present time, we have engaged an outside consultant and as I said before in my talk, we looked at a couple and found that they didn't understand the pilot function to our liking and didn't feel they'd be productive, and we

searched until we found one who did. And we feel we have one, and we're working with that individual right now to develop the program. But to have in-house people that we have on the payroll, as yet we don't have anyone like that.

MR. BRADY: I would have to agree with what my two colleagues have just said and add to it possibly the fact that in the last five years on our airlines we've had outside consultants come in and take a look somewhat into the human factors area on three different occasions in the last five years.

MR. WITTER: I know Bob Houston is busting his buttons to comment, but I want to jump in before he does. We are working for the same organization. All of our management pilots receive formal interpersonal relationships training, not, I think, designed to make you an expert in the area, but to get you thinking about it. In turn, each new captain in American Airlines spends a week following, receiving his airline transport rating in an airplane for the first time in a thing that has become known locally as the charm school. And he, too, receives two days of interpersonal relationships training again designed to get him thinking about it. And I think if we're thinking about it, we're going to make some headway.

MR. FREDRICKSON: We can conduct with the industry in the industry also for a captain's charm school. It's again the two-day school, but we also in our airlines make use of one of the great medical and research centers in the United States, the Mayo Clinic, which is right next door. And we employ no one regularly on a full-scale basis in the human factors field, but we do extensively use the facilities of the Clinic and the psychiatrists and the others that are available at the Clinic and help us in the human factors field.

MR. RALPH: Is there some additional point that you wanted to make as a result of this?

MR. HOUSTON: Well, to supplement what Gordy Witter had to say, I'd -- again it depends as J.D. mentioned, how you define human factors. I would agree at American Airlines we maybe have about a dozen people who might fit in that category. I have three who work for me and included in their responsibilities is an interpersonal skills training and other forms of training that Gordon mentioned.

MR. RUSSELL: I guess I'd like to say something. It seems to me that the question sort of missed the point on my paper. The point that, one of the

points I was trying to make is that the airlines are concerned about the human being in the system. And that available information, they will utilize to make consideration of system changes.

Another point of the paper was that where there is a need for additional information, there are mechanisms to identify this need and the personnel doesn't have to be in an airline to get that work accomplished so long as the people are concerned and want to apply the information available and in absence of information will make the best reasonable judgment at hand. That seems to be the way to be moving.

Thank you.

MR. RALPH: We had a question over here, I believe, that I neglected for about five minutes.

MR. PORITZKY: Sig Poritzky, FAA. I have a kind of a practical question and maybe an impertinent question. The program description that Neal Blake gave yesterday morning of things that are now going on in FAA in the area which we don't call human factors when we have sense enough to say the right words, was a program that sort of happened over the past three years based on a very conscious solicitation of problems, problem statements, from the airlines, from the pilots, from our own internal FAA organizations and many others. And what the program that we currently have is a kind of a synthesis or a meld of programs that you all have identified with a sort of a hopefully a realistic assessment of the facilities that were available and the resources that were available, both of which, as you all know or have become aware, are rather severely limited.

There is an interesting question because, while we have tried to expose that program and have asked, the airlines have asked, ALPA have asked many people in many public and not so public situations, is that the right effort, is the concentration right, are the priorities right? Are we even looking at the right questions? The response we've gotten from the airlines, from most of the organizations, I have to say, has been somewhat underwhelming. There has not been much response, either response that says, yes, what you are doing is reasonably decent or to say, you are crazy, the priorities are wrong. You're looking at the wrong problems in the wrong way or what have you.

My question is this: Is there a way in which we can communicate better and is there a way in which the carriers who are represented up on that platform now could respond better to us, realizing your own resource limitations so that we have a clearer understanding of your needs, your priorities, your thinking about our programs, so that we can do more work in the way in which Dr. Houston described the guidelines which I think are absolutely correct? Is that an impertinent question?

MR. RALPH: No, I don't think so. I think it's right on target, and I don't know -- Yes.

MR. RUSSELL: Well, Sig, this is an interesting thing. I'm trying to play tag with a disappearing target or something like this. As you know you came to ATA and we did, in fact, coordinate amongst the member airlines on views with respect to your program three years ago. But this was a major effort to try and come up with views and by the time we were about to talk with you, you said -- just not you personally, but FAA said, no, we don't have that program any more and it's a much smaller program. And it only involves specific items of application of human factors principle in equipment design. And this has been a continuing -- that was in my view, did happen but in addition it's been sort of a continuing kind of evolution where every time we get just about ready to talk and have a good dialogue, the target moves again. And we may be a part of that process. In fact, I'm reasonably convinced we are. But if we have a mechanism by which we can sit down and have a dialogue and not have it suddenly disappear, we certainly should, with existing communication mechanisms, be able to get airline views to FAA.

People who are with me on the panel here have been involved, and some of the people in the audience, in development of their early comments on what FAA called as the eight-year program three years ago. They will remember that. Others will remember the FAA's process of E and D new initiative and it certainly was a different kind of human factors program presented at that point.

Well, I believe the record will show that we at least said our perception of it was that it was different and where do we go from there? Maybe I turned the question around, but somebody else want to comment on that?

MR. HOUSTON: Yes, I would like to. I would just like to emphasize that my comments, perhaps I didn't make it sufficiently clear, but there is a res-

ponsibility on both sides. There is a responsibility of the agency and, in this case, FAA conducting research, but we in the industry have a responsibility to spend the time and effort necessary to provide the guidance. And I think we have to recognize that responsibility and be willing to spend the time necessary to really properly focus on the problems of questions that are being raised.

MR. RALPH: I think we have time for one more question from the right, please.

MR. CONNELLY: Mark Connelly, M.I.T. My comment is not addressed specifically to the panel but to the record. At this workshop, we have been largely talking about human factors in the small. The human factors as it concerns the individual operator, be it is a pilot or a controller.

Another more difficult problem I feel is the interaction performance of an aggregate, a large aggregate of people; for example, the equipment procedure and the people involved in the air traffic control system. And I think it is possible that we could commit our resources in this program such that we optimize such individual items as the individual controller station or crew station, but that we end up with a system that, as a whole, is grossly inefficient or perhaps even unsafe. We would be in the position of pruning trees while the forest is burning down around us.

Now, I can see that it's extremely hard to do meaningful experiments on large scale systems. Individual human factor studies is difficult enough, but if a large system is where the critical problems lies, then clearly that is the area in which we have to do some research; and I hope that there are enough resources allocated in this program to the macro human factors problem system and aggregates of people as well as the micro human factors problems, the human factors individual.

Now, my own specific obsession, and I guess it is an obsession after ten years or so, is that I feel it's significant gains and capacity in air traffic control could be achieved by giving more information to the pilot so that he can participate actively in the air traffic control process.

Mr. Heimbold of Lockheed this morning was the only panelist to address these larger systems issues with his comments on CDTR and 4D RNAV.

Well, in conclusion, I feel that we all recognize that the air transport industry is in danger of having limits imposed on it by air traffic control restrictions, air traffic control capacities restrictions. And it is possible that this deficiency is not curable by incremental refinements in human factors of the existing system.

MR. RALPH: J.D. Smith would like to respond on that briefly.

MR. SMITH: Well, since you brought up the ATC constraints, any indication that what we're faced with as an industry, it may surprise you to know we got a lot of constraints right and one of the worst ones happens to be right here in this community as far as airport availability and productivity are concerned. And I could bring tears to your eyes if I portrayed all the requirements that people are attempting to place on this industry that are mainly productive as far as taking advantage of either the available airport of productivity or the service to the customer. So you could and all the computers you wanted and put all the information in front of the pilot that he can swallow; but if this industry is going to be plagued with constant attempts, either to price us out of business at airports or inhibit our operation or give us credit for what we've done in the past, it's not going to be worth the powder to blow it up.

MR. RALPH: Those are very strong words. I think they're strong words to end up. Doctor, thank you very much.

MR. ANDERSEN: John, thank you very much. Your panel did an outstanding job.

I realize, everybody, it's late and everybody is getting tired. I promise the last two people coming up here will be extremely snappy. In the spirit that we did invite people who wanted to just make a remark for the record, Dr. Bertone, Sikorsky, would like to just have a minute.

DR. BERTONE: Bert Bertone, Sikorsky Aircraft. This is not for the panel, by the way. This is not a panel thing, so you can relax.

This afternoon I'm speaking not only for myself but also for my colleague, Dr. Doris Struther, chief of human factors, Bell Helicopters and Archie Sherbert, manager of advanced air crew systems design, Boeing Vertol.

We represent three of the four major helicopter manufacturers in the United States and even though each of us have talked individually to members of the FAA, we want to go on record and jointly state our objection to the FAA in not having either a helicopter manufacturer, a user and/or pilot represented on any of the panels in the two-day session on aviation human factors issues.

The helicopter industry is the fastest growing element of the aviation community. We have a projected growth of 12 percent a year compared to 4 percent for general aviation. This means by 1987, a total of over 12,000 helicopters on the airways and a projection of over a half a million trips in the Northeast Corridor alone per year. Of these, it's estimated that one-quarter of them will be IFR operations. The human factors problems we encounter in design, development, certification and flying rotary wing aircraft are in some respects similar to the problems expressed by our colleagues of the fixed wing community. But we have many problems completely unique to our type of vehicle. These include vibration, noise and the unique method of motion and control.

We representatives here from the helicopter industry urge the FAA not to continue to ignore a vital part of the flying community in seeking answers to human factors problems. We jointly encourage the FAA in continuing the dialogue established these last two days but on the next go-around, include not only rotary wing portion of the industry but also representatives of the general aviation community.

One further comment in relation to the format of the presentations. Many of the individuals that I spoke to these last two days indicated that they, as I did, expected a workshop type of interaction rather than a series of presentations with limited questioning after the panel was finished with prepared texts. I think it's most informative to hear what others are doing and how they're solving their problems, which may also be my problems. But to me, a workshop should provide an interactive dialogue, an exchange of ideas and possible solutions, an exchange of information which may not only assist us in solving our problems but will also make FAA more aware of what they should be doing to assist the whole aviation community in understanding and solving the human factors issues in aviation.

Thank you.

MR. ANDERSEN: Thank you, Dr. Bertone. I would just like to say that I was with Jack Harrison, who is going to make the concluding remarks, and I think he'll be talking about the involvement with other elements besides what we had here today. I'm sure he'll be doing that when he gets up, so I don't think anybody else has to comment on that.

John, if you want to lead the panel.

(The panel leaves the stage.)

MR. ANDERSEN: As I said this afternoon we anticipate increased involvement in this research program with the universities. The Department for some time now has an in-place university research program and the reason I want to spend ten minutes with you on this is to explain that the methodology for doing business with the universities is quite different from the normal competitive process or the sole source process or the interagency agreement process. And we thought it would be worthwhile to flash a couple, two or three charts by to show you this only.

Dr. Ravera is still coming back from Washington so Dr. Bob Reck will stand in for him. Bob.

DR. RECK: Thank you. Pinch hitting for Bob Ravera at 4:45 the day before the Thanksgiving holiday starts is a little bit like a situation Charlie Brown faces, that is, it's the last half of the ninth inning, the score is 99 to 0. There are two outs and only the diehards stick around to see if there's going to be a surprise ending. The purpose of my short presentation, as Jim mentioned, is to just make you aware of the fact that the Department of Transportation, in particular the Federal Aviation Administration, has already been working with the academic community on a number of air transportation research areas including aviation human factors. And second, to explain the process used in the present DOT program of university research. Such a process is being considered for use in the university research segment of this new aviation human factors program. That will build on the foundation laid out here on this meeting.

The Department has long recognized that the nation's academic community is a valuable source for innovative capabilities, expertise at the state-of-the-art, objective viewpoints and fresh and enthusiastic resources.



DOT has increasingly supported research work in the academic community. In the past year, about twenty-five million dollars was spent across all the operating administrations of the Department.

The Federal Aviation Administration, as you can see, was the major contributor to much of this work. Some of this work has been on aviation human factors even though we're not quite sure what that is from what J.D. Smith said. Human factors considerations are inherent in all modes of transportation and human factors studies consistently have been among university research projects funded by the Department.

Focusing on aviation, both the RSPA, Office of University Research, and the Federal Aviation Administration have awarded contracts to universities in human factors studies related to aviation. The chart shows a sample of aviation human factors work in the past at a few well known schools. If your favorite isn't up there, there wasn't room on the chart.

Similar work is also ongoing but funded by the other operating administrations of the Department although tailored to the particular problems of those modes of transportation.

I would now like to call your attention to the ongoing multi-model and multi-disciplinary program of university research in the Department. This program is a model for those being considered elsewhere in the Department. Most recently, the cooperative automotive research program known to many by its acronym, CARP, has created an adaptation of this program for its university research segment. This program, of university research is being considered as the basic structure for the university research part of the new aviation human factors. I might add that it has all of the positive attributes that Dr. Bob Houston mentioned a few moments ago. This program started in 1973, has the following major features.

First, the work is undertaken as a contract to the Department. The money is not a grant. The Department gets directed and useful research results and is heavily involved in monitoring and interacting with the universities in its performance.

Each year the experts in DOT define about five to ten research areas, problem areas we call them, to focus the year ahead's research. These areas generally have consistency and continuity from year to year, although the minor elements within them change.

The areas of interest to the Department are structured to appeal to the academic community by designing the work along disciplinary lines.

Finally, the research projects in this program are typically one year but many last up to three years. Project renewal funding each year is based on performance and availability of funding.

I might add that the Operating Administrations can step in at any time and take over the funding of university research programs from the Office of University Research.

The actual mechanics of the program looks something like this: Each year, based on work internal to the Department, and I might add that every Administration in the Department participates in the process, a solicitation book defining the problem areas is prepared and mailed to over 3,000 colleges, universities and researchers across the United States. That solicitation booklet is mailed roughly in May or June each year. The investigators pick the area that interests them and submit a proposal to the RSPA, Office of University Research. Typically, we get 175 to 200 proposals each year. They cut across all modes of transportation. Teams of reviewers focus on the proposals in each of the problem areas and select those within each year they consider worthy of funding.

The review teams evaluate each proposal based on its technical approach, its ability to solve the problem, the management approach and the qualifications of the investigators to do the work.

Next, the five to ten coordinators of each of the problem areas get together and select the proposals they recommend across the various problem areas because the program is budget limited. This always calls for cutting out some good R and D work. Once the coordinators have agreed upon a recommended set, they present their recommendations to a special review board. The board in turn recommends its set of proposals to the administrator who in this case is the approving official. Upon his approval, the Office of University Research proceeds to negotiate contracts to the university, a technical monitor is selected from within the Department who also has expertise in the area of contract and indeed the work begins. Each year about 20 to 30 new proposals are funded. Other monies in the Office each year are used for 15 or so renewals.

We consider the output of the overall proposal process to be vital to the success of the program, and it is something we're continually working on. This chart shows the major ways DOT and the participating universities used to get the research results to the people that can best use them. We are constantly looking for new techniques. I might add that in my book, the proposals that get a better grade put in an extra effort on the dissemination phase of their research. I feel that the program is a good model to use in setting up aviation human factors program. There are many details that time does not allow me to cover, however, I will be pleased to meet with any of you if you are interested and fill you in on any detailed questions you might have.

Thank you for your attention.

MR. ANDERSEN: Before Jack Harrison comes up to speak, I just want to say I really enjoyed the last two days moderating this conference, and I want to thank you for your participation and your cooperation. So now I would like to introduce Jack Harrison, the Director of the Office of Aviation Safety in the FAA, for the concluding remarks.

MR. HARRISON: Thank you. I guess I could thank Dr. Bertone for making a very short speech shorter because I'm going to say we will. I'd just like to simply first reiterate that our goal here is to achieve air crew and controller performance enhancement with a program planned with your input, your assistance and your participation. I think that we all observed here over the last several days that everyone recognizes the existence of problems in these areas, and I would like to express the FAA's appreciation for your willingness to participate in resolving these important safety issues.

What does the future hold? We've established a vehicle, I think, here for an approach to those problems. We will take your input, we will continue with our existing programs and develop them in filling in these missing pieces that are represented by many of the inputs here. We will accept on a continuing basis your input, whether technological or psychological or what have you, how to do it, whatever.

We intend to formulate our programs and divide or subdivide as required and hold further workshops where there can be special or specialized concentration on the different issues. In order to formulate these programs, we intend to continue with workshops and we intend to announce one in the very

near future, perhaps 30 to 60 days, in which we intend to hear views from other airline pilots, business and executive aviation, general aviation, the helicopter or rotary wing people. Craig Beard, we want to hear from people involved in the maintenance and airworthiness areas and last and not least, from those who are involved in the air traffic world.

Our ultimate goal is to resolve safety issues and provide a unified resolution to these problems in our mutual effort to satisfy our obligation to the public expectations with regard to safety and air transportation. I would like to thank and acknowledge not only the panel participants, those who are from ALPA, AIA and ATA, but I would like to acknowledge and express the appreciation of FAA to each and every one of you who have come here to contribute to this program. I would also like to especially acknowledge the efforts of the Transportation Systems Center who did a superb job in putting together this program for us and providing a program that has run very smoothly and looks like we're going to end in a timely fashion, almost on the dot.

Last, I want to thank our own people for their efforts in participating here in this program, our flight operations people, our airworthiness people, our medical people, the engineers and development people and those from the FAA technical center formerly NAFAC and from the Civil Air Medical Institute. I'd thank you from the standpoint of FAA, and I thank you myself.

(Whereupon the convention adjourned at 5:00 p.m.)

ADDITIONAL MATERIALS

## CALL FOR PAPERS

THE 1981 SYMPOSIUM ON AVIATION PSYCHOLOGY  
April 21 and 22, 1981

THE AVIATION PSYCHOLOGY LABORATORY  
THE OHIO STATE UNIVERSITY  
COLUMBUS OHIO  
and  
THE ASSOCIATION OF AVIATION PSYCHOLOGISTS

### THEME

Aviation Psychology since Paul Fitts:  
*Is Advancing Technology Ignoring*  
Human Performance in Aviation Systems?

### OBJECTIVE

The objective of this Symposium on Aviation Psychology is to critically examine the impact of high technology on the role, responsibility, authority, and performance of human operators in modern aircraft and air traffic control systems. Human engineering principles set forth by Paul Fitts for aviation systems will be used as the basis for an examination of modern ground and airborne display and control concepts as they relate to human perceptual, motor, and decisional performance, operator selection and training requirements, and crew coordination.

### DISCUSSION

The role of the human operator in man-machine systems has been changing throughout the history of automation. Because new systems frequently require information processing rates and prediction accuracies far exceeding man's capabilities, a tempting alternative is to limit man's role to supervisor and use a servo as the active control element. Generally, it is more difficult to find solutions that enhance man's capabilities as the system controller. Furthermore, because of their lack of experience with human information processing systems, engineers are less inclined to seek such solutions (Singleton, 1976). Consequently, man is being given a supervisory role consisting of planning, teaching, monitoring, and intervening (Sheridan, 1976).

One of the best examples of the changing role of the human operator in a man-machine system is that of the pilot of a modern airplane. Continuing demands for improved safety, efficiency, energy conservation, and noise reductions with increasing traffic flow have led to increasingly complex systems and control tasks. More and more functions are being handled automatically by ground-based and airborne computing systems, and the pilot is taking the role of a system supervisor who exercises "control by exception" authority only. Nevertheless, despite this increasing role of automation, the pilot remains a redundant system element responsible for manual takeover in the "exceptional" event of partial system failure or other unpredictable contingency that requires improvisation.

In actual practice, the pilot's role as a redundant system element is extremely important. The autopilot is useful during the many "hours of boredom," relieving the pilot of needless attention to aircraft control tasks. However, the autopilot has not been very useful during the "moments of stark terror" (Kennelly, 1970). At the first indication of unusual circumstances (e.g., traffic avoidance, frequent flight path changes, partial system failure, turbulence penetration, passenger discomfort, wind shear, etc.), the pilot's initial action is to disengage the autopilot, whether or not such action is needed. Thus, the autopilot has proved to be most used when the pilot workload levels are low and least used during many periods of high cockpit workload.

In a 1951 report for the NRC entitled, "Human Engineering for an Effective Air-Navigation and Air Traffic-Controller System," Paul Fitts set forth a number of longstanding principles concerning the effective allocation of tasks to men and machines that are studied in human factors classrooms to this day. Among the principles established by Paul Fitts and his colleagues were the following:

1. Human tasks should provide activity.
2. Human tasks should be intrinsically motivating.
3. Machines should monitor humans, not the converse.

Although the tasks of pilots and air traffic controllers at that time were largely "manual" in comparison to today, Fitts could foresee the possibility of conflicts in man-machine task allocations as automation developed.

In our day, the unquestioned motivation behind virtually every technological advancement in the cockpit is "workload reduction". As a result, we have combination control-wheel steering, auto-throttle, and autopilot systems that permit the pilot to assume control of the system at any level in the control hierarchy. A pilot can program his flight on the runway in Paris, take-off and touch only push-button controls until he taxis off the runway in New York. His "workload" is "reduced" under normal flying conditions to the level of a living room observer of Monday night football.

As a result of these "advances", the task assigned to the pilot may be inadequate considering the Fitts principles. The pilot's task requires almost no physical activity, it fails to be intrinsically motivating, and it amounts to a task of monitoring a machine rather than the converse. Furthermore, the low activity level required under normal conditions may compromise the capability of the pilot to assume control during degraded conditions. Thus, the only conditions under which the pilot is overloaded are those cases in which his equipment is degraded. The effect of automation may have been to reduce the pilot's task in normal conditions to a level beneath what Fitts considered adequate without helping and perhaps even hurting his manual control capabilities during flight under degraded conditions.

In addition to the problems of continuous control that are introduced, automation tends to change the requirements for complex decision-making, operator selection and training, and crew coordination. There is a real need at this time for a critical examination of the impact on our aviation system of engineering "solutions" before they find a "problem" that may not exist. The 1981 Symposium on Aviation Psychology will provide this critical examination in a series of tutorials and paper sessions given by experts in the field. This Symposium will be unique in that it will concentrate on a solution

to the critical problem of the allocation of tasks to operators and machines during this time of increasing automation in aviation systems. In particular we will seek to determine whether the Fitts man-machine allocation principles are applicable today and to identify what additional information is yet needed concerning human capabilities to exploit the recent advances in technology for aviation.

Scientific papers are invited reporting the results of research relating to the Symposium theme in the following areas:

1. Pilot-Cockpit Interface
2. Pilot Judgment/Decision making
3. Pilot Selection and Training
4. Crew Coordination and Size

Please send abstracts of proposed presentations as soon as possible to:

R. S. Jensen  
Department of Aviation  
The Ohio State University  
P. O. Box 3022  
Columbus, Ohio 43210

Include brief biographical sketch(es) of the author(s).

Although papers presenting research results are preferred, scientific papers of interest and value to equipment designers and FAA rule makers are also invited. The abstract deadline is January 30, 1981. Please indicate your intentions by filling out and returning the enclosed form.



THE 1981 SYMPOSIUM ON AVIATION PSYCHOLOGY

April 21 - 22, 1981

Name \_\_\_\_\_

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\_\_\_\_\_ I will attend.

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Send to:

R. S. Jensen  
Department of Aviation  
The Ohio State University  
P. O. Box 3022  
Columbus, Ohio 43210

Please suggest others who should receive this notice.

Name \_\_\_\_\_

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Joint Symposium with Ohio State

- a. Good idea as long as the agenda is relevant.
- b. Joint symposium might involve Ohio State asking for a few dollars in support. This is OK.

Kansas City Letter

No problem including the letter and attachments in the Proceedings (although the letter seems irrelevant).

A. Broderick for W. Luffsey, 12/9/80, 9:25 AM



**Aviation Department  
Kansas City International Airport**

City of Kansas City, Missouri  
Heart of America

P.O. Box 20047  
Kansas City, Missouri 64195

816/243-5200

November 19th, 1980

Dr James Costantino, Director  
Research and Special Programs  
DOT Transportation Systems Center  
Kendall Square  
Cambridge, Massachusetts 02142

SUSPENSE 12-9-80	
ACTION	DATE
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Dear Dr. Costantino;

Again, please accept my regrets for not being able to attend your invited aviation human factors workshop on November 24th-25th. If you judge appropriate, please include this letter and attachments as part of your composite workshop report to the Administrator.

As I see it, aviation human factors efforts have concentrated mainly on airfield, cockpit, and pilotage problems and have virtually ignored human factors issues of the large, world-class commercial airport.

Last year alone, in the United States, there were 317 million enplanements; each enplanement representing an important human event in an environment beset with unresolved human factors problems.

Dramatically for example, more people die in large commercial airports than in commercial air crashes. I'm convinced, that most of these airport deaths are directly precipitated by the airport stress experience. Proof: Study the first-aid medical reports of large commercial airports.

Should not this 1st workshop on air safety also concern itself with airport stress hazards?

As a "quick and dirty" summary, the following list, I believe, represents some of the important human factors problems of the large, world-class commercial airports:

- 1- Stress hazard to travelers;
- 2- Information retrieval;
- 3- Accelerated time perception of jetports and its impact on passenger dissatisfaction;

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page 2

- 4- The need for environmental intimacy;
- 5- De-Humanization anxiety produced by transient environments;
- 6- Handicap Accessibility;
- 7- Special travel needs of older citizens;
- 8- Community interfacing problems, e.g. noise; negative aura ;
- 9- Impact of various architectural designs on the delivery of human services;
- 10- Educational resource potentials of airports;
- 11- Spaceport conversion planning for the future space traveler.

As a further partial elaboration of this theme, i.e. airport human factors, I have attached excerpts from a paper that I recently submitted to the AAAE.

I hope that this letter helps sensitize the aviation factors industry to the important human facets generated by the "Great Pyramids of our Times", i.e. the large commercial world-class airports.

Sincerely,

Michael Morra Ph.D.  
Assistant Operations Manager

cc: Delbert Karmeier, Director

If in fact, we are truly dealing with the "Age of the Passenger" as an evolutionary reality, we must come to grips, in a very practical manner, with its factors, e.g. behavioral, sociological, etc. For example, one pivotal factor for us to consider might be to assay the effects of the basic architectural design of airports on passenger/manager relationships. An isomorphic study of the four major airport designs (i.e. centralized, decentralized, hierarchical, and linear) could, very well, reveal an important correlative relationship between management efficiency and passenger needs. Practically, this might be translated into less passenger complaints and better community and press relations.

Analytically, it seems to me, that a centralized airport design, is least sensitive to passenger needs, yet easiest to operationally manage. This design seems to be one which promotes "herding" rather than environmental intimacy. Passengers are handled as faceless humanoids, who blindly traverse the airport stalls and because of its inherent impersonal qualities ignores the human inclinations of travelers. In this type of milieu, a passenger must certainly feel like a member of a flock, with marginal identity, and set in a field devoid of environmental warmth.

On the other hand, a decentralized airport design, although plagued with built-in logistical problems, duplication of services, difficult security, and perceptual vastness seems to be most sensitive, at least in potential, to the effective development of human/passenger sub-systems and programs. Operationally, it is possible to easily incorporate workable human sub-systems and creative programs. This minimum resistance, produced by the inherent airport design, expeditiously enhances the quality of airport psychological life. Short-walking distances, pervasive handicap services, sparse automobile traffic, minimal building crowding, ample privacy, reduced noise pollution, effective information, multipurpose delivery sub-systems, and a general regard for personal space, all characterize the decentralized airport layout.

Overall, the best balanced and most efficient airport design concept is the hierarchical type. Very simply, this design, by utilizing vertical space, combines, coordinates, and integrates similar and compatible passenger functions by layers or tiers. This arrangement, inherently, produces very effective delivery of passenger sub-systems with relatively minimum management effort. Both the needs of the passenger and the rights of the manager are optimized. I would predict, as some proof of these conclusions, that a controlled study would reveal that the hierarchical airport design produces the least number of passenger complaints in most areas of airport operations.

Finally, the linear airport design is one which fails to produce an identifiable concept. It simulates a montage; a series of mini-airports dominated by a string of airlines. An airport is not a series of airlines; an airport is not aviation; an airport is not an airfield; an airport is an airport; a community building block with clear integrated identity and with many complex roles and responsibilities to fulfill. The managerial/passenger relationship in a linearly designed airport is difficult to attain, is inherently dysjunctive, and grossly limited in potential. This type of layout lacks definition, identity, cohesiveness, and organizational integrity. An airport manager's role seems hopeless limited to "landlord".

In the conventional practice of airport management, there are on-going, hard-core, psychological, sociological, cultural, and community problems to deal with, yet often ignored. These human problems have their "echos" at the very core of operations and maintenance management. Who will deal with these issues? ex-combat officers? civil engineers? self-serving bureaucrats?

The following are some specific examples of these hard-core behavioral issues:

- (1) The chronic impact of accelerated time perception produced by the emanations of any modern jetport is one such phenomenon which raises traveler's anxieties. This negative psychological state is at the roots, I am convinced, of most passenger complaints. Passenger stress produced by the aura of speed, must be identified, de-fused, and minimized with specialized management sophistication.
- (2) Another major and inherent psychological contaminant, produced by any jetport, is the negative aura of impersonality. The "no one cares about me" or "I'm only an object" feeling. Existential philosophers have long noted this modern disease and we as managers of the "great" structures must cure it at the operational level. No doubt, this phenomenon is at the roots of passenger negativism. The obvious counter-force is the creation of environmental intimacy.
- (3) Professional evaluation of the nature, frequency, and substance of passenger complaints should be a regular management practice. It is a type of organizational evaluation and re-evaluation which is the most reliable and valid indicator of a manager's performance. It is the pulsebeat of streetside management. Unfortunately, I suspect that most, if not all, senior airport managers in this regard, practice some sort of "ostrich" management.
- (4) To deal with streetside matters, an airport organization must have a formalized and continuing passenger relations training program, for all airport employees, i.e. that includes field and building maintenance workers, administrative personnel, security, etc. This type of major commitment by senior airport managers strongly acts to resist bureaucratic and impersonal delivery of direct and indirect passenger services. The payoff is quick.

A passenger relations program must be tailored, appropriate, and practical. It must include employee selection processes, human-awareness training, proficiency programs in the delivery of airport information, and a credible employee discipline response.

- (5) Health hazards, as yet unmeasured, seem to exceed the ordinary constructs of industrial safety. In itself, air travel is stressful, especially to the phobic, the elderly, and the "first-time" passenger. Furthermore, to most passengers flying on "important" trips, air travel can prove to be emotionally difficult. A systematic review of first aid reports of any large airport would reveal, I'm convinced, a relatively high incidence of cardio-vascular and metabolic medical emergencies. At large airports and as compared to a community of comparable population size, these medical emergencies might prove to be significantly greater. The principal stressors associated with an airport experience seem to be: (a) the meaningfulness of a particular trip; (b) the usual frantic airport routine; (c) the act of flight itself; (d) individual physical and mental state, and (e) the age of the passenger.
- (6) The handling of the dissatisfied, the "down-right" irate, the mentally disturbed, the deranged, and the violent-prone passenger requires a special effectiveness in human relations. Security, safety, supervisory, and management personnel all require some sort of training, clear policy expectations, and the assurance of organizational "stroking" in order to deal confidently, competently, and humanely with the upset traveler.
- (7) Information retrieval sub-systems need continuous updating, field testing, and monitoring. This is an important, critical, and pivotal function in passenger relations. Nothing is more grating to a traveler than to receive incorrect, incomplete, or inadequate information. No doubt, this is the primary and most pressing need of any passenger and requires the expertise of communication specialists.
- (8) The Handicap Act of 1976, the EEOA of 1972, and the Civil Rights Act of 1964 all require operational monitoring, implementation, and compliance at the everyday "grass-roots" level of airport operations management.

- (9) Any senior airport manager who has been taken to task by the press, local politicians, or citizen's group, is aware of the importance of perceiving an airport in the context of the community. It would be folly to view the airport a "synapse" in the transference of faceless, humanoids from place to place. Efficiency, as the overriding motive in the delivery of airport services is not enough. Social responsibility, commitment to the education of school children, providing on-site experiences for university students, sensitive awareness to the surrounding environment, and special events for community "pleasure" are all part of the mission of airport managers.
- (10) Finally, passenger sub-systems which require continuous monitoring, development and improvement can be categorized in four classes: (1) Basic Comforts; (2) Information Retrival; (3) Distractive Activities; and (4) Mobility.
- (1) Passenger Sub-Systems: Basic Comforts
- (a) Oral
  - (b) Excretory
  - (c) Sanitary
  - (d) Orderliness
  - (e) Privacy
  - (f) Safety
  - (g) Security
  - (h) Child Care
  - (i) Fear-Reduction (e.g. liquor)
  - (j) Medical Services
  - (k) Dental Services
  - (l) Handicap Services
  - (m) Temperature Regulation
- (2) Passenger Sub-Systems: Informational
- (a) Signing
  - (b) Telephones
  - (c) Displays
  - (d) Maps
  - (e) Brochures



- (f) Handouts
- (g) Airport Employees
- (h) Foreign Language Services
- (i) Pictorial Language

(3) Passenger Sub-Systems: Distractions

- (a) Background Music
- (b) Work and Writing Space
- (c) Grooming Services
- (d) TV and Movies
- (e) Gift Shopping
- (f) Reading Materials
- (g) Religious Services

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- (f) Traffic Control
- (g) Traveler's Aid

HUMAN FACTORS IN ACCIDENT INVESTIGATION

by

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Presented at the Dutch Air Line Pilots Association Meeting  
"Safety and Efficiency: the Next 50 Years,  
A Symposium on Human Factors in Civil Aviation"  
The Hague, The Netherlands September 6, 1979

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#### NEAR TERM SOLUTIONS FOR WORKLOAD ASSESSMENT IN APPLIED SETTINGS

Although many efforts have been conducted, and many efforts are being conducted in the workload area, the results of such efforts will be in the future. However, there is an immediate need to improve workload assessment to deal with new aircraft and operating environments which can change the roles which crewmembers perform. Current workload assessment technology may not be appropriate to deal with this situation, and it is not feasible to wait until long-term efforts are completed. Thus, there needs to be a review of workload assessment for near-term use considering what is currently available and what will be available in the future.

Although aircraft are forcing improved workload assessment technology, aviation is not the only area where an understanding of workload is needed. The nuclear power industry, for example, also must understand workload. Other industries, as well, need to understand this elusive concept in the design of more productive and efficient job organizations. All these groups are faced with the same problem of insufficient technology to currently assess workload, but at the same time needing solutions in the near future even though research will not have answers for some time.

Therefore, it is proposed to present a workshop dealing with the assessment of workload for near-term solutions recognizing that current research must be continued to yield long-term results. Although targeted at near-term solutions, the work-shop will significantly impact long-term efforts as well.

The proposed workshop will have two basic elements of tutorials and roundtable discussions. The tutorials will address the history and procedures employed in previous workload assessments while the discussions will address key questions to establish the components of near-term workload assessment technology. Specific recommendations for techniques which can be immediately implemented will be solicited so that the end result of the workshop will provide a tangible set of items for use in the near future.

A suggested list of tutorials are:

1. The Federal Aviation Regulatory Process: the manufacturer proposes; the FAA disposes.
2. The History of the Workload Regulation - Apperfix D: how it came about; how it was implemented in prior certifications of the Boeing B-737 and B-747, the Douglas DC-9 and DC-10, and the Lockheed L-101'.
3. Guidelines for implementing Appendix D: Proposals for the FAA Flight Test Guide
4. State-of-the-art Workload assessment technologies: Government Views (FAA, NASA, DoD); Aircraft Manufacturers; other agencies
5. Long-term futures for workload assessment
6. The Role of the Current and Future Aviation Environment on Workload: Air Traffic Control procedures; cockpit automation; advanced displays
7. Single pilot operation and the future environment: IFR and VFR without cockpit automation

NOTE: All tutorials will have representatives from different aviation groups representing commercial aviation, general aviation (commuter, private, rotorcraft). Naturally, the workshop is targeted for researchers.

Suggested questions for roundtable discussion are:

1. Define "workload": workload from an operational position; influences and interactions with fatigue, stress and circadian rhythm
2. Relation between workload and performance measurement: where does one start and the other stop; where is there an overlap; what techniques can be taken from one and used in the other
3. The dimensions of workload: what multi-dimensional profiles are required for workload; how do the profile elements interact
4. Validation of workload assessment: characteristics of workload reliability and validity; available "yardsticks" for comparisons; other formulations of reliability/validity
5. Objectivity versus subjectivity: A moot question? Are subjective measures as useful as objective measures?
6. Targeting workload levels: How critical is underload, overload? Establishing optimum workload levels
7. A workload philosophy: Active and passive (monitoring) roles for personnel and equipment
8. Influencing factors on workload: personnel training, procedures utilized; standardization of equipment and procedures
9. Interference and workload in new situations: automation; advanced procedures
10. Impacts of workload on FAA: cockpit standardization of equipment and layout; procedure standardization; impacts on certification techniques and regulations

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## ABSTRACT

Despite the continued citing of human factors in a major proportion of aircraft accident findings, the understanding and application of the human factors field has been minimal. Whereas medical and crash survivability investigations have been extensive, at least in air carrier accidents, human behavior including pilot error has only relatively recently begun to be approached on a systematic basis. Accordingly, this paper summarizes a number of the analytical concepts that have been applied across the spectrum of human factors accidents. Specific recommendations are reiterated which have been offered in the past. A renewed plea is made to accident investigation authorities, airlines et al to take the necessary action to address the human factors investigation problem and thus prevent accidents.

## HUMAN FACTORS IN ACCIDENT INVESTIGATION

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### INTRODUCTION

Especially in the past few years, the international aviation community has demanded, if not actually given, more attention to human factors investigation technology than any other branch of the systematized art of aviation accident investigation. The International Society of Air Safety Investigators (ISASI) had human factors as the theme of both its 1971 and 1978 annual symposia. 1, 2/ The U.S. Air Line Pilots Association (ALPA), the International Air Transport Association (IATA) and the Flight Safety Foundation have held meetings at which the theme may not have been human factors investigation per se but the lessons gleaned from these meetings was unmistakably clear. 3-6/ One of the main reasons accidents continue to occur is the inadequate attention given to human factors during investigations. More often than not, oversimplified reports are presented which seem to have more application in the media or the courtroom than in accident prevention.

The above somewhat pessimistic view notwithstanding, there have been improvements in knowledge of how to attack the problem. Unfortunately, however, much of this knowledge has been lost among different industries, different countries and differing disciplines. Accordingly, an attempt is made in this paper to highlight certain basics regarding human factors investigations of aircraft accidents, describe some approaches to the investigative task which appear valuable, and assess those continuing problems for which all of us in the aviation community have an obligation to help solve.

### HUMAN FACTORS IN ACCIDENT INVESTIGATION DEFINED

Gerry Bruggink, recently retired Deputy Director of the NTSB Bureau of Investigation and certainly one of the world's authorities in air safety, proposed a working definition of investigative activities dealing with the human role in accident causation as follows:

The systematic search for the probable reasons why personnel directly involved in the operation of a flight did not, or could



not, interrupt the event sequence that terminated in the accident or incident. 7/

He deliberately separated this from the survivability investigation albeit he conceded that conceptually, injury causation belongs under human factors. Also he stopped short of including the formulation of recommendations in the accident investigation task and concentrated on those persons "directly involved." This was probably due to his desire to avoid "trying to be concerned with the grand design of society" and keep the investigation within practical limits of relatively pure fact finding.

One may argue with these limits (as has this author in correspondence with Mr. Bruggink), but one cannot fault the key phrases in his definition ... "reasons why" and "interrupt the event sequence." These acknowledge the fundamental meaningful quest for underlying factors in every investigation and multiple cause-effect relationships implicit in every accident.

This author has drawn a broader picture of human factors as may be applied in investigation as illustrated in Figure (1). Created originally in 1965, this concept shows man as a subset of a larger package of factors which bear on safety or conversely, can be the breeding ground for hazards or accidents. Man interacts with the machine, the medium (environment) and the mission, and is latched to management. As such it is oversimplified at best in an investigation to examine the man alone albeit some things are clearly under his sole control. Most hazards are a matter of interface problems; hence this theory suggests the investigation must be structured to assure application of knowledge beyond the man alone as an operator, support crew member, passenger or whatever. 8/

This "5M" concept is not as different from Bruggink's definition as one might suspect at first glance. His asking for answers as to why the person could not interrupt the sequence, will bring in the interfacing factors.

Contrast the above concepts with the ICAO Investigation Manual which states:

The prime object of the Human Factors investigation is to obtain evidence as to the cause, sequence and effect of the accident through an examination of the operating crew, the cabin attendants and the passengers. 9/

It implies singular cause which is rarely if ever the case. It also implies examination of only the people. It helps explain why most human factors investigations in the past have been in the purview only of pathologists or other physicians.

In any case, step one in understanding human factors in accident investigation is to appreciate it means different things to different people and the trend is to broaden the scope of human factors investigations.

## MODELS OF PRESENT HUMAN FACTORS INVESTIGATIONS

The semantics game in the preceding sections notwithstanding, it is possible to describe the scope of human factors investigations by looking at fundamental approaches or analytical models actually being used. No attempt is made herein to present them in depth since to do so would require creation of one or several books. Hopefully, however, the point will be made that techniques are available to do a complete human factors investigative job and all that is needed is for someone to say do it ... and fund it.

### 1. Human Error

Human error is probably the most visible of the human factors studies in an investigation but also one of the most misunderstood. Four interpretations have been identified by this author in the past. 10, 11/

First and most common is the blameworthy mistake model. As described by Meister, Swain et al, human error in this context is:

- (1) Performance of a required action incorrectly (error of commission)
- (2) Failure to perform the required action (error of omission)
- (3) Performance of a required action out of sequence (a sequential error)
- (4) Performance of a non-required action (an extraneous act)
- (5) Failure to perform the action within the allotted time (a timing error). 12, 13/

Second is the task overload concept. As illustrated in Figure (2), the theory suggests that accidents occur when degraded capability of the person involved (a pilot in this instance) overlaps the task loading imposed by other aspects of the system. 14/ This could also be thought of as the behaviorist approach since behaviorists normally think in terms of task analysis.

Third is what can be deemed a matter of data convenience or what was not too facetiously referred to in the past as the "convenient cubbyhole" approach. 15/ It arises when accident analysts need some system to classify and store data contained in reports submitted by investigators. It can be very comprehensive as indicated in Figure (3) which is a U.S. Department of Defense classification of psychophysiological factors. 16/ It could also be so simple in the "why" sense as "Failed to see and avoid" or "Failed to extend landing gear" which are categories of human error found in the NTSB coding manual. 17/ These classifications usually stop very short of suggesting practical remedial solutions and too often go back to the blame connotation although everybody who uses them maintains they are not investigating to establish blame.

Finally there are occasionally accident prevention classifications such as Pierson's "Taxonomy of Pilot Error." <sup>18/</sup> His theory was to assess available event information in terms of what avenue seemed to be most productive in accident prevention. Major categories chosen were:

- (1) Design-oriented pilot factor
- (2) Operations-induced pilot factor
- (3) Environment-induced pilot factor
- (4) Innate pilot factor.

The presumption in this approach is that some qualified persons would conduct the analysis and make the findings in peer group review fashion that, for example, a design change was the most practical way to prevent the error revealed by the facts.

What this discussion of human error means is that one had better decide why the information is being collected before settling on a language to be used. Also, be realistic and be ready to identify differing interpretations of the same words describing human error.

## 2. Man-Machine Behavior

Several expressions of man-machine behavioral flow patterns have been developed over the years as typified by Figures (4) through (6). <sup>10, 19, 20/</sup> They attempt to portray the fundamental perception-decision-response behavior of man as influenced by external stimuli and memory and consequent control of the machine which then changes the input stimuli. This becomes a valuable tool in the investigative process to ensure, for example, that decision errors are not really perception errors due to a filtering effect; or perhaps the memory link is deficient because of a training deficiency. In other words diagrams like these and others to be noted supra aid in developing the "whys" discussed earlier.

## 3. Information Processing and Decision Making

A close cousin to the preceding man-machine behavioral approach and one of the more comprehensive approaches developed in the last few years is illustrated in Figure (7). This emphasizes information processing during the decision phase which is presumably where the person can be more readily guided through regulation education or training. <sup>21/</sup> This work ultimately conducted by NASA was energized in its early phases by airline pilots and NTSB personnel in an informal cooperative manner which is a story in itself. The project was instrumental in the implementation of the Aviation Safety (Incident) Reporting System under the superb direction of Dr. Charles Billings of NASA's Ames Laboratory. <sup>22/</sup> The program recently survived an attack by some prejudiced and uninformed FAA personnel which suggests the soundness of the information acquisition, storage and analysis techniques of the program.

Table (1) is a companion to the NASA program. <sup>23/</sup> It is a very convenient list to use in assessing information transfer problems, i.e. the fidelity of the pathways shown in Figure (7).

#### 4. Man and the System

Figure (8) takes the task overload approach and examines how system components combined with psychological and physiological states produce human control of the situation or, as the case may be, human error. "Components" in this sense are those entities — supervision, environment, facilities et al, which experience has shown have the greatest effect on human performance. This U.S. Army analysis technique has had several years application with encouraging results. <sup>24/</sup>

It should be noted at this point that these concepts are not just untried theories. For example, Figure (4) has been used by this author numerous times to examine cases such as the American Airlines B727 accident at St. Thomas, V.I. <sup>25/</sup> ALPA has used Figure (6) in their examination of the Tenerife catastrophe. <sup>26/</sup> Investigators at NTSB used Figure (7) in analyzing segments of the Eastern Flight 66 crash at JFK Airport albeit the final report did not so indicate. One of the young air safety investigators at NTSB, Ron Schleede, has been trying to apply these techniques to general aviation accidents. <sup>27/</sup>

#### 5. Health and Physiology

One should not forget this oldest of areas in which human factors concern has been applied in accident investigations. No diagrams are necessarily available to illustrate the scope of this field. Table (2), however, is an outline of material traditionally covered by Dr. Charles Barron of Lockheed when he lectures to safety students at the University of Southern California, as he has been doing for nearly two decades. The subjects portrayed therein speak for themselves. <sup>28/</sup>

#### 6. Crash Injury Investigation

Similar to the health and physiology subject, crash injury investigation is neither new nor mysterious. It is just time consuming and requires high quality professional skills as do all aspects of human factors investigation. Shown as Table (3) is an outline of crash survivability factors used by this author over the years in teaching as well as analyzing accidents. They form a checklist of investigative areas for which specific techniques are well known.

#### THE EFFECTIVE APPROACH

Given the understanding of the subject and analytical tools, only a portion of which having been described above, what remains is to grasp how to best implement the effort. Lt. Col. MacNamara et al from Canada have illustrated the first step. See Figure (9). They emphasized the firm setting

of an objective of zero human error accidents and looked at their own system to see how the parts could be integrated to reach that objective. 29/

Second is the use of incidents as well as accidents as the investigative basis. No human error elimination program will be effective without it. Without fail, the incident investigation system should have provisions for confidential communications and a reasonable balance between immunity from censure and personal accountability.

Third is the matter of using time-line analyses. For reasons unknown to this author, investigators tend to be reluctant to add the time dimensions to their analyses. Perhaps it is because firm behavioral time standards applicable to stress situations are not readily available from research. Also without cockpit voice recorder (CVR) and flight data recorder (FDR) records, time sequencing during the event is a poor guess at best. Still there are reasonable limits that can be applied which, when combined with physical evidence, can be quite meaningful.\* Clearly this is an area of needed research and documenting of experiences which may be the only way to quantify perception-decision-response time under stress.

Fourth is the question of how to organize to conduct the human factors investigation. Certainly, severe problems have existed in U.S. civil aviation in this regard, due primarily to unwillingness of certain NTSB Board Members and members of the Board's senior staff to break with the past. 11, 31, 32/ Traditionally, operations groups have tried to cover human performance factors aided and abetted on occasion by flight surgeons and aerodynamicists. Human factors reports usually turned out to be merely discussions of the crew's pathology and crash survivability. What was wrong with these approaches was the lack of interdisciplinary skills applied to the task.

Human factors evaluations of any reasonably complex occurrence will usually require inputs from several disciplines. Listed in alphabetical order (to deny the supreme importance of any one of them), the people needed could be:

- Anthropologists
- Engineers
- Manning and Training Specialists
- Operational Personnel
- Physicians

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\* Using this approach, this author was able to show that a 10,500 ft. runway was not long enough to allow successful abort in a CV880 when a control problem was perceived at  $V_p$ . The Administrative Law Judge found in the pilot's favor in an action initiated against him by the FAA. 30/

- Physiologists
- Psychologists.

If these people are not readily assignable, it becomes necessary to train the generalist investigators sufficiently in each field to know when to call for help. Thus the organizational makeup is secondary to the skills being applied and willingness, as Bruggink has also suggested, for the Investigator-in-Charge to establish a Human Performance Group, a Medical Group, or whatever group the situation merits. <sup>31/</sup> The mistake is to believe human performance et al is a natural output of one of the classical groups when members thereof are not trained in the intricacies of the question at hand. Being human does not an expert in human behavior make!

It is difficult for most people to appreciate the most fundamental human factors lesson of them all ... there is a difference in what man can do and what he will do. It is difficult for most people to appreciate man's adaptability becoming a positive influence in safety even under conditions of increasing hazard. <sup>31/</sup> Figure (10) illustrates this but also shows the benefits from hyper-awareness may last just so long. Without this phenomenon, however, how does one explain good safety records at airports with abominable approaches? (e.g. Hong Kong or Washington National)

It is difficult for all of us to see the same kinds of human error accidents repeated year in and year out.

#### RECOMMENDATIONS REVISITED

In a presentation at a Flight Safety Foundation seminar in 1974, this author recommended six items to help resolve problems associated with human factors investigations in aviation accidents. <sup>31/</sup> These included:

1. A human factors indoctrination program for senior aviation officials
2. Development of a practical human factors investigation protocol
3. Promulgation of policy statements regarding incident reporting importance compared to punishment or censure by both government and industry
4. Declarations by airlines that CVR records would never be used by them in disciplinary actions
5. Probable cause determination either eliminated as a statutory requirement or so defined as to eliminate single causes
6. Research to secure more personal performance information during accident/incident investigations, confidentially if necessary, without jeopardizing personal rights in the process.

Three years later, this time at an ALPA meeting, five more recommendations were offered: 32/

7. CVR fidelity and timing accuracies should be improved ... consider renaming the device a Cockpit Sound Recorder (CSR) since that is really what it does.
8. Install CSR's in at least representative general aviation aircraft - at government expense, if necessary.
9. Institute more use of simulators early in the investigation any time crew performance is at issue.
10. Restructure NTSB and ICAO code books to delete blameworthy terminology for human factors descriptors in use today.
11. Provide more in-depth investigation into training and provide more coding of the results.

Based upon an NTSB letter response to a personal inquiry of them plus other observations to date, only items (6) and (8) have been accomplished and only partially at that. 34/

Accordingly only one new recommendation is offered and it is addressed to those government and industry leaders who can make and implement decisions regarding aviation accident investigation.

Please read and try to understand the recommendations made by this author among many others to try to improve human error accident investigations. Act on them and thereby prevent accidents.

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Figure (1)

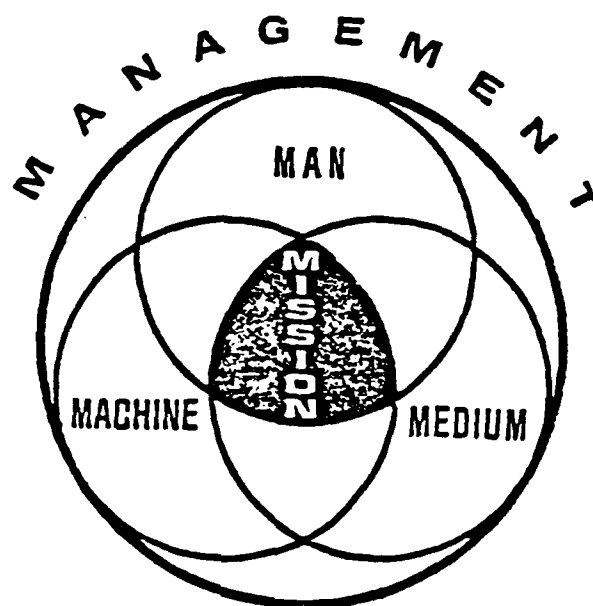
SYSTEM SAFETY FACTORS

Figure (2)

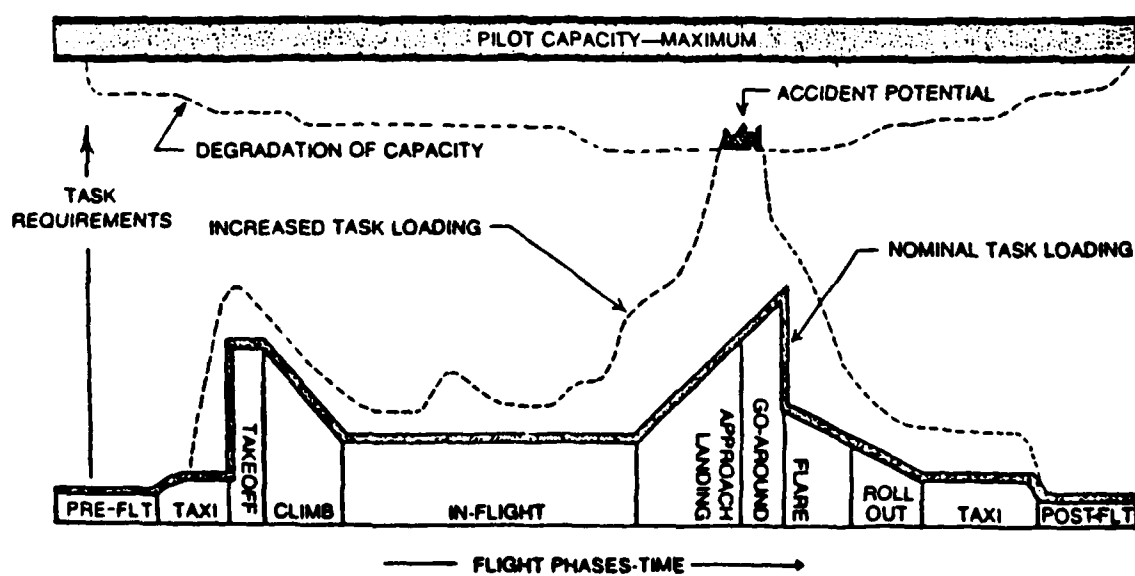
PILOT CAPABILITY AND WORKLOAD



Figure (4)

## MAN-MACHINE BEHAVIORAL FLOW PATTERN

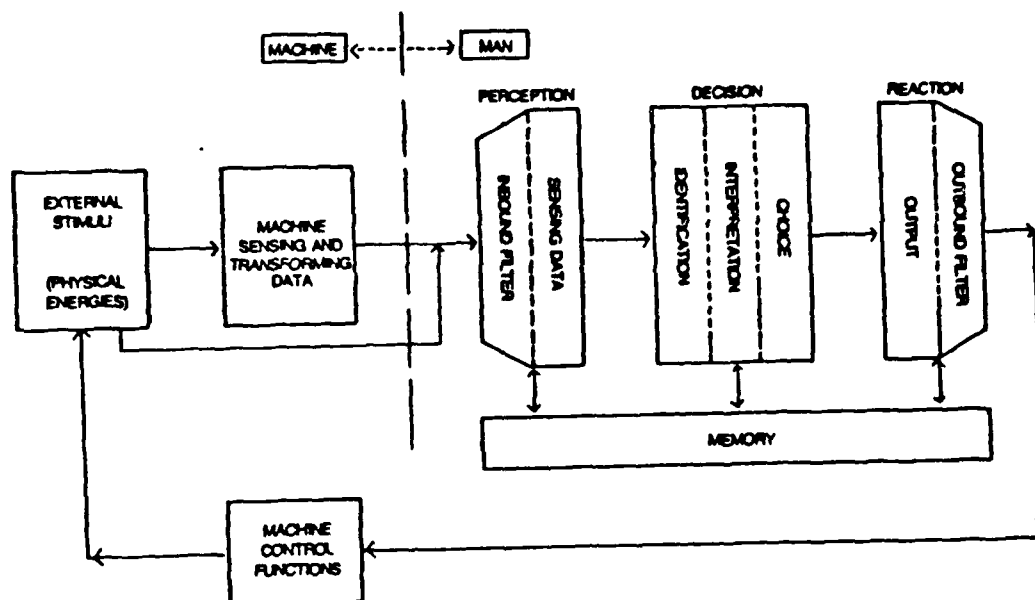


Figure (5)

FLOW DIAGRAM OF THE INFORMATION PROCESSING SYSTEM

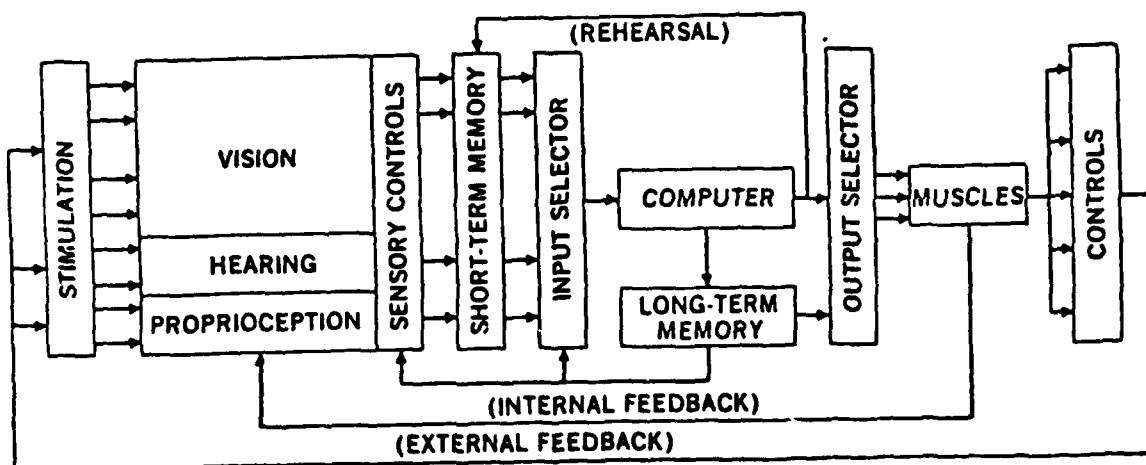


Figure (6)  
Human Information Processing System

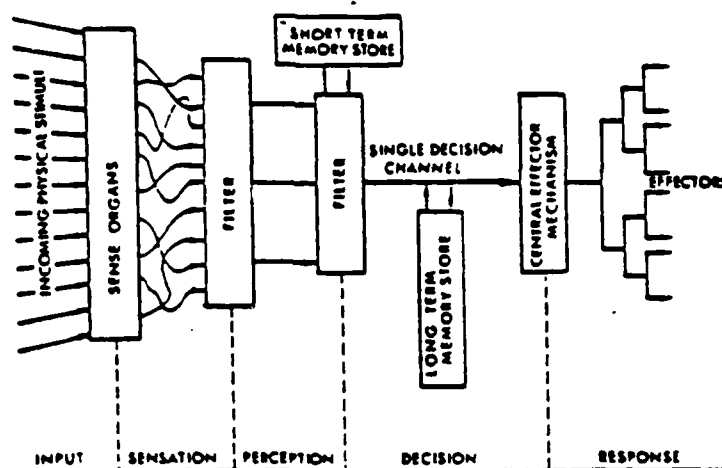


Figure (7)  
(Please see next page)

Figure (8)

USAAAAYS MODEL OF THE HUMAN-ERROR ACCIDENT

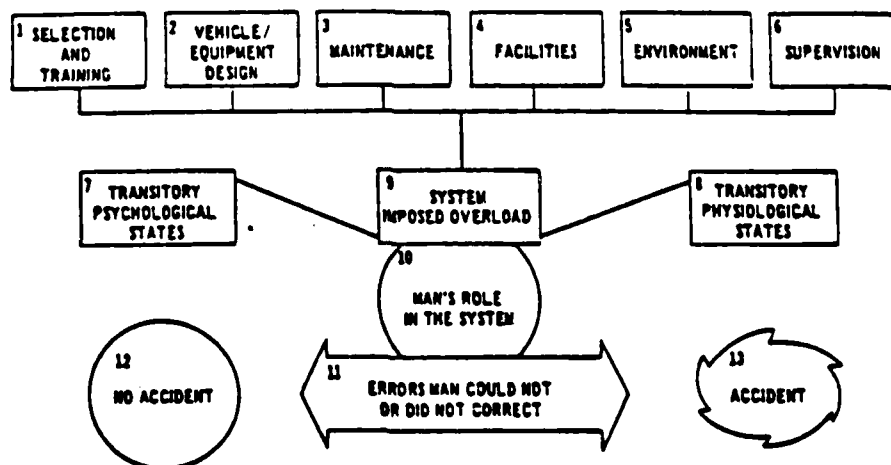


Figure (7)

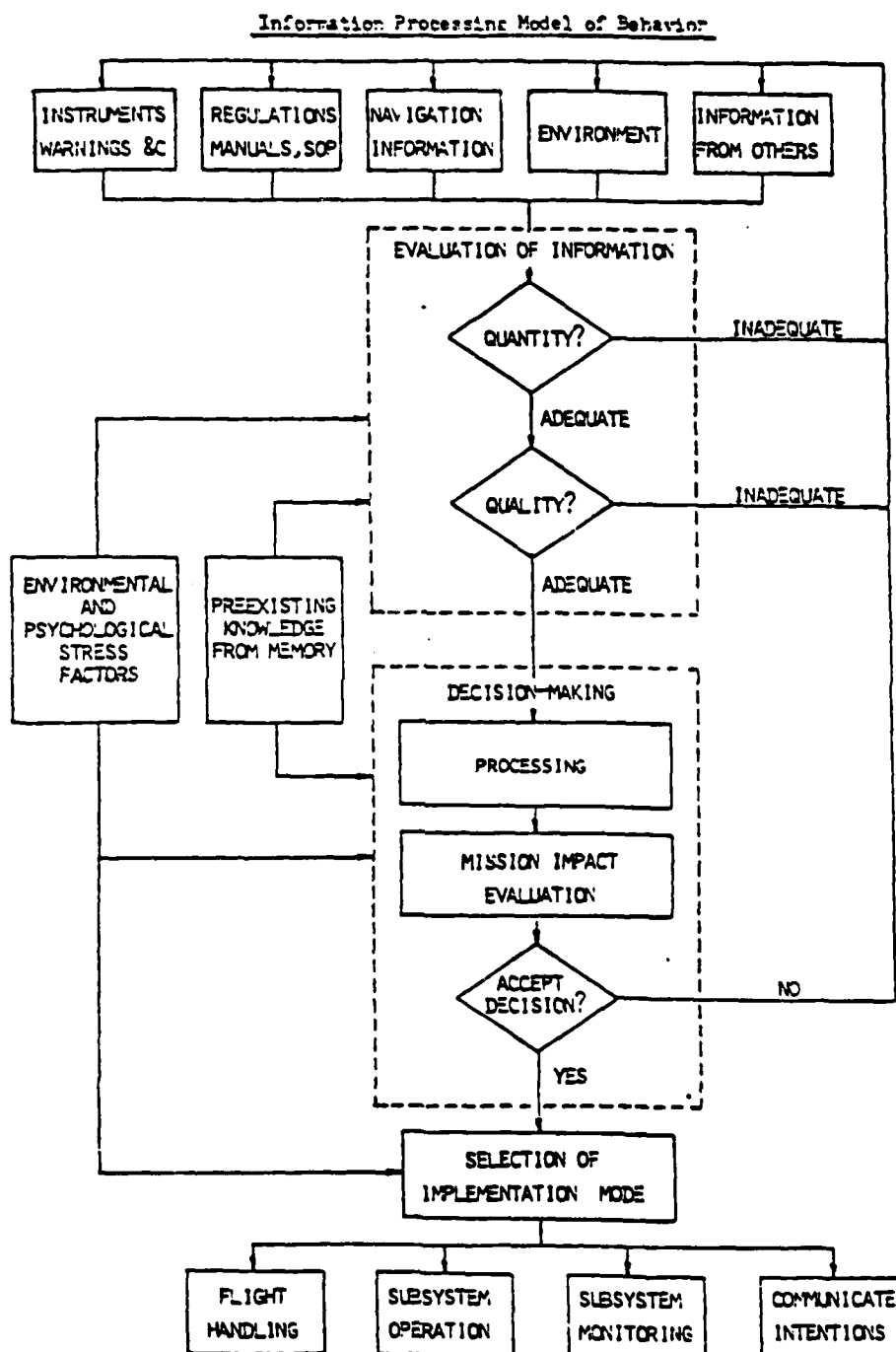


Figure (9)

Analysis of Human Factors  
in Aircraft Accidents

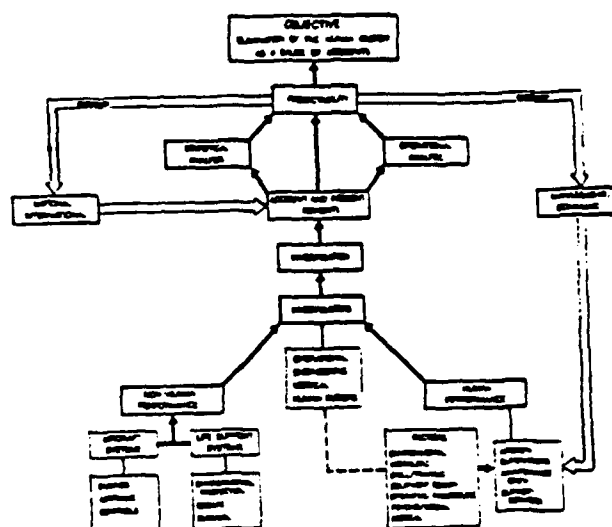


Figure (10)

LEVEL OF SAFETY VS DEGREE OF HAZARD

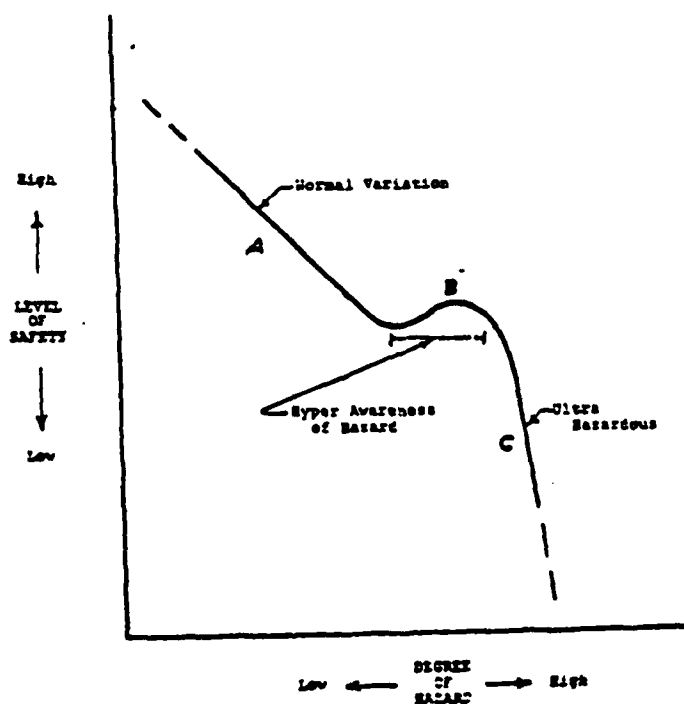




Table (1)

## INFORMATION TRANSFER PROBLEMS

<u>Information Content</u>	<u>Information Transfer</u>	<u>Information Reception</u>
Information not available	No means of communication or presentation	Information not perceived
Available but incorrect	Low signal-to-noise ratio	Perceived but misunderstood
Conflicting information	Language/symbology barrier	Significance not appreciated
Correct but ambiguous	Non-standard phraseology or presentation	Cognition impaired:
Correct but not credible		Physiological factors
Correct and acceptable	Ambiguous communication or signal	Psychological factors
	Overload: too much signal	Information understood, then forgotten
	Information available but not located	Information understood and retained
	Correct, timely communication or presentation	

Table VI

HEALTH AND PHYSIOLOGY FACTORS

<u>Aspects of disease</u>	<u>Personal or habit stresses</u>
Coronary heart disease	Nutrition
Brain hemorrhage	Drugs
Psychiatric disorders	Smoking
Gastrointestinal conditions	Alcohol
Other acute disorders causing incapacitation	physical conditioning
	Fatigue
<u>Conditions causing medical disqualification</u>	<u>Environmental stresses</u>
Heart and circulatory	Altitude
Psychiatric	Speed motion
Traumatic injury	Visual
Gastrointestinal	Thermal
Musculoskeletal	Noise
Eye	Fumes
Cancer	
Metabolic (diabetes)	

Table (3)

## BASIC ELEMENTS IN CRASH SURVIVABILITY

<u>Mechanics of injury</u>	<u>Post crash fire</u>
Basic physics	Fire mechanism and severity
Impact dynamics	Incidence and characteristics during accidents
Human tolerance	Toxicity of materials
<u>Crashworthiness</u>	<u>Emergency egress</u>
Structural integrity	Cockpit/cabin crew communication and coordination
Systems integrity	Performance under stress
<u>Restraint system</u>	External environmental factors
Belt-shoulder harness	Evacuation slides
Seat tie-down	Deployment and ingress to rafts
Energy absorption	<u>Rescue and survival</u>
<u>Internal environment</u>	Location and access to wreckage
Adjacent structure	Ground personnel effectiveness
Loose objects	Medical treatment
Compartments, galley equipment, etc.	Remote area survival

## ABOUT THE AUTHOR

As a pilot, engineer, educator, federal executive and consultant, Mr. Miller has acquired international recognition in his air safety activities spanning a quarter of a century. He is a former Director of the Bureau of Aviation Safety of the U. S. National Transportation Safety Board (1968-1974) and was Director of Research and Lecturer at the Institute of Aerospace Safety and Management, University of Southern California (1963-1968). Among several honors bestowed upon him, Mr. Miller was named recently a Fellow in the Human Factors Society for his career efforts in advancing the human factors discipline. He holds a Bachelor of Science degree in Aeronautical Engineering from the Massachusetts Institute of Technology and a Masters degree in Systems Management from the University of Southern California. He is currently enrolled as a final year law student at the Potomac School of Law, Washington, D.C.

## HAZARD ANALYSIS AND IDENTIFICATION IN SYSTEM SAFETY ENGINEERING\*

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### ABSTRACT

The complex aerospace system of today presents a formidable challenge to all engineers in terms of identifying and attacking hazards during the design process. Safety engineering has the unique role of *assuring the application of the bitter accident lessons of the past, especially at interfaces between subsystems*. This paper examines first, the hazard analysis methodology spectrum; second, it reviews hazard identification concepts. The result is an attempt to further delineate the principal system safety contribution during the design process.

### INTRODUCTION

Under the banner "Galloping Technology: A New Social Disease", a psychiatrist recently wrote:

"Man has been characterized as the only creature with an infinite capacity for making trouble for himself, and we seem to be fully exercising that capacity today... Perhaps it is not too much to hope that the same qualities which enabled him to triumph over the destructive forces of nature will enable him to master those he himself has created."<sup>1</sup>

The author was not really talking about hazard analysis, but he could have been. Beginning in the powered flight control systems of the early 1950's, through the inadvertent drop of a special weapon over South Carolina in 1958, and through the total impact of the Apollo 204 tragedy, we have indeed pondered our ability to combat the ill effects of a galloping technology.

We like to think that we have exercised our intelligence in the safety engineering field to help ourselves "master these (hazards) he himself has created". We have more analysis techniques than most people can recap at any one sitting. Indeed, perhaps this is the basic problem. We have so many approaches

to hazard analysis, that their true perspective has been lost somewhere along the way. Each inventor of a new analysis wrinkle now has the answer... but quite often he forgets the question.

As of this writing, MIL-STD-882 is under consideration as a replacement for MIL-S-38130A, the basic system safety engineering specification. A major section of this document involves hazard analysis.<sup>2</sup> There is considerable activity in non-aerospace safety fields to acquire and utilize aerospace developed analysis techniques.<sup>3</sup> There is a mushrooming propensity towards more documentation of hazards in this era of super data requirements. The need to better clarify the analysis picture has never been more timely than it is now. A better perspective is needed, else the confusion become compounded further.

This paper shall attempt to provide a framework for utilizing hazard analysis methodologies and the data contained and/or derived therein... which introduces a fundamental point in itself.

Analyses techniques are discussed first and then the hazards. This serves to emphasize that the techniques are, or should be, chosen before the hazards are really known. At least if one enters an analysis process only with a preconceived checklist of hazards and is satisfied once they are ticked off "yes" or "no", he has not truly exercised the total preventive power of analysis techniques. The end of the analysis process, such as strict adherence to a contract requirement, numerical or otherwise, does not approach the value of the means... provided that means involves qualified people with imagination and a questioning attitude, and a penchant for taking accident prevention action whenever and wherever they find the opportunity to do so.

One further note of introduction entails use of the term hazard analysis rather than safety analysis. This serves to emphasize the need to avoid analyzing something to determine its safety. In accident prevention, one analyzes to identify, minimize and control hazards. If safety levels must be established for management consumption, do not confuse that with accident prevention. It is even tempting to include "hazard analysis" in favor of "accident prevention", or "loss prevention", or "risk management" analysis.

\* From:

1968 Annals of the Assurance Sciences  
(New York: ASAF, 1969)

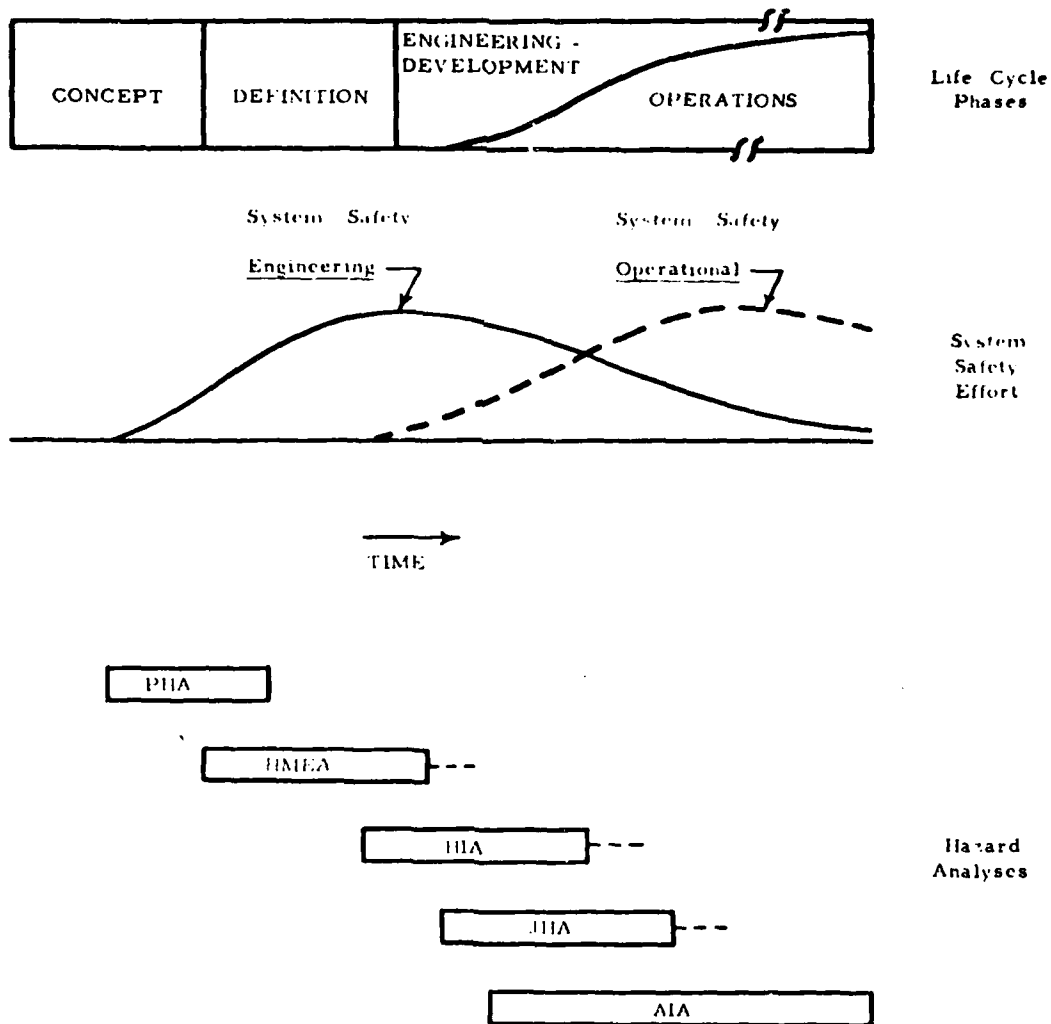


Figure 1... SYSTEM SAFETY AND HAZARD ANALYSIS

But the aerospace community is not ready for that yet!

### THE ROLE OF HAZARD ANALYSIS IN SYSTEM SAFETY

Much of the existent misunderstanding about hazard analysis results from a similar limited view of the total system safety process. System safety has differed from previous accident prevention activity in really three ways:

- (1) The "System" encompasses much more than just the air vehicle. It could include support equipment, facilities, the people involved, training programs, etc. Or, it could be applied to any identifiable segment of the whole.<sup>4</sup>
- (2) The accident prevention scope involves planning and control on an entire life cycle basis; from conception of a system through its operational phase.
- (3) There are specific safety tasks contracted in the engineering phases to supplement those conceptually similar efforts going on during operations.

The life cycle relation of system safety engineering to operational safety is portrayed in the top two segments of Figure (1). Observe the overlapping nature of inputs from operational safety personnel and safety engineers. Do not, however, interpret the vertical magnitude of the efforts or the phasing of one relative to the other in the precise sense. Such factors not only go well beyond

the scope of this paper, but also they would vary with the type of program under consideration.

Another interesting portrayal called the "Professional Safety Task" was prepared by a special committee of the American Society of Safety Engineers.<sup>5</sup> Note Figure (2). Observe the terms "identification", "appraisal", "control", and "measurement". These are highly indicative of the hazard analysis process and suggest analysis must be fundamental to any professional endeavor... in this case that of the safety engineer.

Viewing the system safety life cycle en toto (a precept that should continually be observed by safety specialists), five basic types of hazard analyses are proposed. Their phase relationships are indicated in the lower part of Figure (1). Each is discussed herein.

**Preliminary Hazard Analysis (PHA).**... This becomes the earliest evaluation of the system. Indeed, step number one is a careful delineation of the system to be considered. Often, this is not adequately accomplished since one tends to take a system look only at that part of the package for which he may be contractually obligated. The fact remains, someone must document the boundaries of the system, possible interfaces that may have to be examined later, and subdivide the system into manageable packages. Some of these packages, safety-wise, become the responsibility of the contractor; others may remain within the sphere of direct influence by the customer, e.g., certain aspects of personnel or facilities programming.

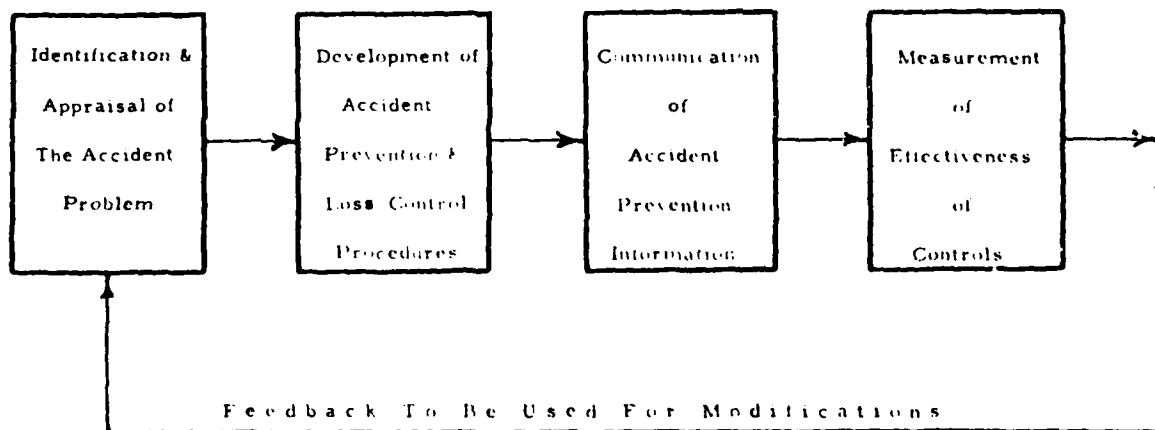


Figure 2... THE PROFESSIONAL SAFETY TASK

Other delineations are made in terms of configuration, mission profile, operational segment, or even specification applicability. This may readily be a systems engineering function primarily. However, it may have a profound effect on all safety analyses to follow; hence, it requires input from system safety engineering.

The principal SSE task in the preliminary hazard analysis phase entails what MIL-S-38130A has termed the gross hazard area. These include such items as energy source considerations, hazard properties of fuels and propellants, compatibility of materials, crashworthiness, training for safe operation, etc. "These areas represent classification of known precedent in accident causation that are intersystem in nature", according to DII-1. They require a "gross" look even at the earliest stages where major configuration choices or other decisions are reached that have an overwhelming effect on hazards downstream.

An example of this might be the location of engines or fuel tanks in a portion of the aircraft cabin as a function of crashworthiness. At the most early phase, this could be influenced by a safety suggestion to possibly use crash activated fuel shutoff valves or the latest concepts in crash resistant fuel tank materials.

Hazard Mode and Effects Analyses (HMEA).... This might be better titled "subsystem safety analysis", although many of the techniques utilized herein also examine subsystem interfaces, thus assuming a system meaning. Hence, the more general HMEA title was selected.

The distinguishing feature of this group of analyses is their being accomplished in the two dimensional sense, analogous to the basic design drawing task. They come in many shapes and sizes. They are qualitative and quantitative. They are called many things: Failure Modes and Effects Analysis, Fault Tree Analysis, Energy Transfer Analysis, Catastrophe Analysis, Time Sequencing Analysis, Fault/Hazard Analysis, Failure Mode and Criticality Analysis, Bruceton Analysis, Nuclear Safety Analysis and probably many more. The Electronics Industries Association's System Safety Engineering (G48) committee has attempted to document these in the past year or so without significant success.<sup>7</sup> Not only does a semantics problem exist, but many of the procedures are not in distributable form according to their proponents.

Fundamentally, however, HMEA's assume some type of functional or nonfunctional hazard. They

then examine symptoms of the hazard; possible causes, detection methods; effects on the subsystem under study, other subsystems and/or mission; and compensating provisions present including influence by the crew. A hazard classification level is also usually introduced to lend some priority to the finding and/or adhere to a contractual requirement concerning levels of hazards.\*\*

It is important to recognize that HMEA's do not treat only failures as may be done in a reliability analysis. There are unsafe acts of people (omission or commission) and environmental conditions that must be considered as well as mechanical failures per se.

Finally, the end product of the HMEA must be recognized. As stated by the USAF Space and Missile Systems Organization Safety office:

An analysis is performed not to satisfy the requirements of the safety military specification, but to contribute a worthwhile product to the system design. Each safety task should be performed with a definite purpose, and produce meaningful, useable results. There is little purpose in performing a hazard study if that study identifies hazards without providing methods to avoid them in the design. This approach to a hazard study can be compared with standing by the freeway at rush hour, deciding it is hazardous to cross, and then crossing anyway.

Total delivery of a completed analysis contributes little to the over-all program primarily because of its complicated nature. Evaluation by the program office requires as much time and talent as is required for the contractor to perform the analysis. The contractor should provide a summary of the analysis results, showing the areas investigated, those undesirable situations found, what was done to the design as a result of the discovery, and what trade-offs were made, if any.<sup>8</sup>

Indeed, the principles contained in that statement are applicable to any phase of analysis.

Hazard Integration Analysis (HIA).... If the HMEA is subsystem oriented, then this phase can be considered system or subsystem integration oriented. In many respects it represents an integration of both the PHA and the HMEA. However, the distinguishing

\* DII-1, the System Safety Design Handbook published by the USAF Systems Engineering Group at Wright-Patterson AFB, Ohio... a "bible" under development for system safety engineers.<sup>6</sup>

\*\* This author considers hazard levels as defined in MIL-S-38130A to be totally impractical to introduce in the hard contractual sense beyond using them as relative assessments for descriptive purposes.



feature here is use of the three dimensional world. Emphasis is once again placed on the "gross" hazard areas and those derived during HMEA; but the methodologies change from head scratching and check lists to mockups, simulators, prototype hardware and test vehicles.

It must be recognized that there are human limitations in the assessment of hazards on paper. One does not see control rod interferences in a two-dimensional drawing, nor does one eliminate them by merely putting out an instruction to maintain X inches clearance. One does not detect the subtle meaning of a wire bundle being scraped by an access panel in the vicinity of a combustible material by limiting his analysis effort to conferences at his, or someone else's desk. It can be argued that HIA is perhaps more fundamental to the safety discipline than is the HMEA which was most certainly conceived in the reliability field.

System hazard integration analysis area is not well-defined in the literature and represents a challenge to safety engineers to do so.

**Job Hazard Analysis (JHA)**... The terminology here is chosen in deference to its heritage dating back well before aerospace safety engineering became a well defined activity.<sup>9</sup> Current techniques labeled operating hazard analysis, manufacturer's and testing hazards analysis, and certain operator error analyses are basically the same as job hazard analysis. They are distinguished by the introduction of the real world man-task relationship into the hazard picture. (More will be said shortly about the human variable in its total contribution to hazard analyses).

The precept must be recognized that limitations occur in the previous analyses, pertaining to assumptions made about what people will do in their association with a system. This is often

different from what they can do. It is necessary to not only forecast the human input to hazard causation as well as possible, but also it is necessary to literally bring the person aboard himself as a participant in the analysis process. If a corollary safety motivation benefit is desired, the man's supervisor should also be present.

Job hazard analyses as defined above have their place beginning in manufacturing, continuing through testing and into operations phases. They may have a heritage during HMEA, but ultimately end up with the operational people, using operational hardware in the operational environment. They may also have to be repeated as a function of changing operational environment.

Once again, there are probably as many formats for job hazard analyses as there are people accomplishing them. They fundamentally entail, however, a basic job task, a description of a specific method to accomplish the task, potential hazards, and subjective assessments of what countermeasures can be employed.<sup>10, 11</sup>

**Accident/Incident Analysis (AIA)**... All too many safety engineers fail to recognize the importance of accident/incident analyses as an integral part of the hazard analysis spectrum. Its significance is best illustrated in Figure (3). To be sure, the emphasis should be placed on the before-the-fact procedures. However, both accidents and incidents provide a vital feedback loop that tests the validity of the other analysis techniques as well as inevitably revealing hazards that had not been identified earlier.

Techniques of accident/incident data are again quite varied. It is generally agreed among experienced safety engineering personnel, however, that statistical summaries have little meaning other than to point the way to areas of more detailed investigation. More often than not, this means access to and

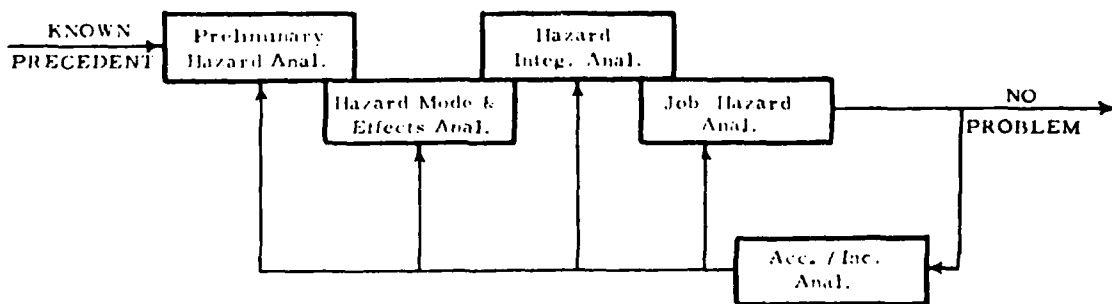


Figure 3... THE HAZARD ANALYSIS SPECTRUM

review of the accident/incident reports themselves.

As implied earlier, the human variable, especially human error, merits special consideration in discussing hazard analyses. It is a matter not only as a contributor to hazard per se, but also is at the heart of problems attendant to quantification of safety.<sup>4, 12</sup>

Human error has been defined by several authors. (References 13 - 18.) At least one author has taken the trouble to attempt to marry the human error problem to the other parts of the system in interactionist model form.<sup>19</sup> Task analysis is the accepted methodology followed by human factors engineers/psychologists wherein human error data could be an important factor therein. Whatever technique is used, however, must recognize the combination or sequence of events that is present in virtually every accident, and not try to approach human error on a single causal factor basis.

Practically speaking, human error must be introduced in all the hazard analysis phases described earlier. To do otherwise would be to negate one of the fundamental precepts of accident causation. There is no known model of the anatomy of an accident that does not include the man per se, an unsafe act, or a deficiency in his performance as described by lack of education or failure to adhere to laws or procedures. What should be accomplished is a highly coordinated effort between human factors and system safety personnel.

An even more difficult consideration, perhaps, is the integration in planning and accomplishing the five hazard analyses described in this section. They do not fall neatly in the normal purview of a given organizational segment at either a contractor, or the customer. Still there can be little exception taken to the need of coordinating the efforts, with each subsequent analysis building upon the activities of the previous one. Such efficiency is a prerequisite in the systems management concept.

#### IDENTIFICATION OF HAZARDS

"Analysis" literally means separation of things to find out essential parts. In the mathematical sense, the meaning goes on to suggest that the process is performed to solve problems.<sup>20</sup> What the literal translation does not do is explain where the data comes from to "feed" the process.

This fundamental point was driven home to the author while lecturing in an accident investigation in the past. In attempting to describe to students what to be on the lookout for, it became apparent that--regardless of the subsystem under review--certain

items would repeat themselves. For example, a "Murphy"<sup>21</sup> can occur in any subsystem. Interferences caused by environmentally induced stresses are not subsystem peculiar. Other examples are endless. Still, if there was a total logic to such lessons learned, it was certainly not apparent at the time.

Only two reports encountered by this author seem to address themselves to this problem.<sup>21, 22</sup>

Mr. Harold Adams, a superbly experienced design executive of the Douglas Company at Long Beach, California offered one approach in 1959. His fundamental premise in design safety is to extend experience. Hazard prevention during the design phase is achieved in three ways. "Mechanical failures" must be attacked through what he described as a failure mode and effects process. "Human failure" is to be attacked by simulation. "Design failure", (unseen requirements or combinations leading to a critical situation), are attacked by "imagination".

Mr. Adams' division of hazards applicable to aircraft disclosed the following:

- a. Structural failure
- b. Power failure
- c. Control failure
- d. Navigation equipment failure
- e. Fire
- f. Physical danger to crew
- g. Collision
- h. Pilot error (judgement, technique)

Types of failure related to hazards were listed as follows:

- a. Rupture (open circuit or excessive deflection)
- b. Jamming (short circuit)
- c. Runaway (failure to stop)
- d. Reverse operation
- e. Untorseen operation
- f. Secondary failure
- g. Human failure (Design induced & stress induced)

A second more recent study was conducted by Mr. Willie Hammer, formerly of the USAF Directorate of Aerospace Safety where he had been on the receiving and reviewing end of accident reports for many years.<sup>23</sup> Mr. Hammer provided a hazard analysis logic based on four factors: hazard, occurrence, cause, effect.

<sup>21</sup> A part that can be installed incorrectly, will be installed that way.

<sup>22</sup> Mr. Hammer is now a member of the staff of the Walter V. Sterling Co. of Claremont, California.

Mr. Hammer stressed there could be multiple entrees for a given term, (e.g., fire). He classified hazards as follows:

- |                             |                          |
|-----------------------------|--------------------------|
| a. Acceleration             | l. Pressure              |
| b. Contamination            | m. Radiation             |
| c. Corrosion                | n. Replacement Chemical  |
| d. Disassociation, Chemical | o. Shock & Impact        |
| e. Electrical               | p. Stress concentrations |
| f. Explosion                | q. Stress reversals      |
| g. Fire                     | r. Structural Damage     |
| h. Heat & Temperature       | s. Toxicity              |
| i. Leakage                  | t. Vibration & noise     |
| j. Moisture                 | u. Weather & environment |
| k. Oxidation                |                          |

It is not evident from the above list that the human variable becomes involved, but this enters the scheme of things through Mr. Hammer's discussion of "occurrence", "cause", and "effect".

Implicit in both Adams' and Hammer's work is the necessity for subsystem classification, e.g., hydraulic system, propulsion system, etc. DH-1 is a good illustration of such an approach. This becomes, then, still another dimension of the hazards hierarchy. Of course, how does one determine the depth within a system to which hazards are investigated, or in what life cycle phases? What is the system state under investigation? Which hazards are the prerogative of other personnel besides safety specialists? It becomes apparent that relatively sophisticated data processing systems will have to be applied if and when a more comprehensive hazards matrix is described. Only in this manner can areas not investigated be efficiently identified, corrected, or bought-off by project management.

In the interim, it behooves the system safety engineer to take multi-directional cuts at feeding the hazard analysis process. First might be types of hazards on a subsystem basis. Next, might come types of failures as a function of system state, or in combination with subsystem configuration. Or to return to Mr. Adams' point, use imagination!

It is firmly believed that accident data classifications do not satisfy the needs for adequate feedback into the hazard analysis procedure. In their stored computerized form, they provide mainly what happened and do not identify the causal factors in sufficient depth or breadth to be of value to the design or safety engineer. They are primary (singular) cause oriented which actually denies a fundamental factor in accident anatomy; that is, the sequence of events.

It can only be concluded that a formidable task faces the system safety fraternity. A better hierarchy of specific hazards and their related dimensions must be established which can be used in the analysis

process. To do otherwise would be to continue to not learn from the mistakes of others. And no one lives long enough to make them all himself.

## CONCLUDING REMARKS

There are several areas related to hazard analysis and identification that have been encountered in the preparation of this paper; areas that are subjects unto themselves requiring development elsewhere. For example, what about the integration of hazard analyses with other analyses performed in the system development process? Management appreciation for system safety engineering is not going to be enhanced by unplanned duplicative effort.

The entire safety information field requires a more sophisticated approach to subject indexing of its data... and certainly the utmost coordination in this respect if the professional safety discipline is to mature.

The legal ramifications of hazard analysis have still not really been appreciated, although the subject was first broached by this author in 1962.<sup>23</sup> Simply stated, care had best be taken that reasonable care has been exercised in performing hazard analyses. Hidden or destroyed data is no defense in the widening trend towards open records at both contractor and government facilities.

There is an alleged conflict between qualitative and quantitative approaches to safety. It would seem such a conflict melts a nothingness however, if the total scope of hazard analysis is recognized. Each has its proper place.

There are many benefits to be derived from hazard analysis that are not directly applicable to the design but do aim towards accident prevention. Unfortunately, such pay-offs as better inputs to education and training programs, or assistance in accident investigations rarely gain the attention they deserve.

The above postscripts notwithstanding, this paper has attempted to delineate methodologies as compared to mythologies. It has attempted to show that some system life cycle approach should be considered for hazard analysis if system safety is really the name of the game. It has offered a challenge to the safety engineering profession relative to hazard identification... if its members are to be prepared for even more professional work in the future. Perhaps the paper has really just provided an arena for further arguments!

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*Cliff  
Harris*

November 26, 1980

Mr. John R. Harrison  
Director, Office of Aviation Safety  
Federal Aviation Administration, ASF-1  
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Washington, D.C. 20591

Dear Jack:

It seems to me that when an organization puts in the time and effort to put on a meeting such as the recent "Human Factors Workshop", attendees ought to make such constructive response as they are individually able. That is what I am attempting to do in this letter. I wasn't really certain how to direct this letter and so I've addressed it to you, Jack, believing that you will pass it on as you see fit.

I noted with interest that there appeared to be some uncertainty as to who is a Human Factors practitioner and who is not. This came to a head when a question was addressed to the Tuesday afternoon "Operator's" panel as to exactly how many Human Factors people each represented organization had on their staff. I sensed a bit of academia in the question, perhaps meaning "How many psychologists with specialized college training in Human Factors?" Most of the responses to the question referred to personnel department staff, extensively experienced air line pilots engaged in training, etc. I believe that all of these people are indeed Human Factors practitioners. I'm an electrical engineer with no college training in Human Factors but I have devoted the majority of my professional career to the study of human visual performance. Perhaps a better question would have been, "How much emphasis does your organization place on attempting to understand and improve human performance?" Obviously the operators have an entirely different set of needs than the equipment manufacturers, for example, who have to face very specialized Human Factors problems such as are encountered in the design of new cockpits. In my view, anyone who is attempting to understand and improve human performance is a Human Factors practitioner and any attempt to restrict the definition is counter productive. We can expect different kinds of contributions from different regions of the spectrum of practitioners. From the more academic we can certainly hope

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that study and research will lead to new understanding and theory of human performance which will be of wide benefit.

As Administrator Bond said in his opening remarks, this meeting was not the place for solutions but rather for identifying problems and developing sense of direction. Unfortunately it is necessary to start out with some attempt to survey who is currently doing what. As people present their work, of which they are proud, they may tend to give the impression that they have all of the answers. This can have a negative impact on a meeting intended to identify problems. In this regard, perhaps first meetings are a necessary evil which we must endure because we are not smart enough to know how to have the second meeting first. One tangible result of the meeting is that it causes people to rethink and reorganize their general thoughts about the subject, just as I am doing in the process of writing this letter.

There is one other comment which I would like to make relative to the important task of exposing problems. There are often some strong practical factors which inhibit this process. For example, I believe that the FAA faces serious limitations in being able to mount a high vitality research effort directed toward improving air traffic control performance. The starting point for any such effort must be a lucid description of all of the present limitations. Who in the FAA is going to author such a paper, knowing full well that it will be used against them in the inevitable litigation following every ATC related accident? Other organizations face somewhat similar problems.

I believe that there was a justifiable uneasiness as to the standardization arguments which arose in response to the use of the drum altimeter. I'm sure that standardization imposes some very difficult limitations for both manufacturer and operator but it's a long wait for the new generation aircraft and it hardly seems necessary to retrain flight crews because of the substitution of an easy to read altimeter. Surely such problems are not insurmountable. Nor is it comforting to someone like myself to be told that there is a lot more to the problem than I understand, even though I'm certain that is indeed the case.

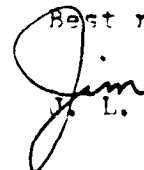
One thought which occurred to me and which I also heard expressed independently by two other attendees has to do with trying to recognize and anticipate rather than eliminate human errors and then find ways of minimizing the impact of such errors on performance. For example, with today's micro-processor technology it should be an easy task to monitor

power, flap control, etc., settings with a display which indicates the phase of flight operations implied by this combinations of inputs. If the combination of inputs does not correspond to any legitimate flight operation then either the pilot would be so advised or intervention would take place, this option requiring substantial study. It seems ludicrous in this day and age to allow accidents such as a takeoff with incorrect flap settings, for example.

I would think that a follow-on workshop should include a portion of time in which the group is subdivided into a series of smaller groups, each dealing with some specific aspect of aviation safety. Each group would be charged with coming up with a specific list of problems targeted as potential targets of Human Factors effort. Because of my own personal interest and involvement, I would hope that this would include See & Avoid and Landing Operations under minimum visibility conditions.

A response to this letter is not required. I just wanted to pass along these random thoughts for what, if any, value they might have to those planning follow-on activities. It was good to chat with you again. I hope you'll have the chance to drop into my office so I can show off my computer facility.

Best regards,

  
J. L. Harris, Sr.



## **Cockpit Management Resources**

**CAPT. ROBERT W. MUDGE, Director**  
**P. O. Box 969, Center Harbor, N. H. 03226**  
**Tel 603-253-6963**  
**November 24, 1980**

DOT/FAA Human Factors Workshop on Aviation  
Department of Transport  
Transportation Systems Center  
Kendall Square  
Cambridge, MA 02142

Cockpit Management Resources would like to express its appreciation for being invited to participate in this Workshop. We are a new Company being formed because of basic beliefs which seem relevant to the objectives of this Workshop.

We believe that:

- 1.- Research related to cockpit management, to be effective, must be:
  - A.- Presented in a style easily understood by pilots (every discipline has its own vernacular).
  - B.- Packaged into a training system designed to have a maximum potential for producing behavioral changes.
  - C - Designed to deal with real-world problems of concern to cockpit managers and affecting flight safety, flight efficiency and passenger service.
- 2.- Useful information from other disciplines (such as sociology, psychology, business management, etc) must be handled in a fashion similar to 1A, B and C above.
- 3.- We must apply what is known about interpersonal relationship to the flight deck situation and train cockpit managers to utilize this information for the benefit of the flight mission.

- 4.- We must learn more of pilot traits, intellectual needs, motivations, etc, to bring about personal development so as to help him prepare to handle unusual situations and to properly monitor automated systems effectively.
- 5.- We must package what we know of cockpit management into a useful training system to be made available to captains, perhaps as a part of an upgrade program. This program must be flexible and designed to produce desired behavioral change.
- 6.- While it is likely that initial emphasis will be on the needs of the professional airline or corporate pilot, whatever we learn from our studies of cockpit management must be packaged for other pilots as well - general aviation, military and even the FAA.
- 7.- Beyond this we must also recognize that the early establishment of proper behavioral patterns consistent with good cockpit management is extremely important. How much easier it is to teach a 50 hour pilot the proper scan pattern than to attempt to correct a scan pattern in a 20,000 hour pilot. Accordingly, we believe that a serious effort should be made to prepare training programs for the undergraduate student in college flight programs and then expand these to all elementary flight programs.
- 8.- Finally, we must recognize that formal instruction of our instructors must be undertaken. Even today we tend to assume that because a pilot may be in a check or instructor position that he is automatically competent to teach cockpit management methods. This is not necessarily true.

It is our hope that future Workshop agendas will include some of these concerns.

The invitation to this Workshop indicated a desire to review current programs and make suggestions concerning them. Since ours is a very new program, we feel we could benefit from such comment (and by this paper specifically invite them), and also that perhaps other participants might be interested in what we are doing to attack the problems mentioned above.

While subsequent programs are planned for other pilot groups, our initial effort is directed at the airline and corporate pilot. It is entitled:

**Cockpit Management**  
**An Interactive Learning Experience**

It is based on instructional technology, written in a pilot's language, deals with real-world problems that concern the cockpit manager, and is designed to have the highest probability of producing favorable behavioral changes.

The program is written and designed by a professional pilot with technical writing and training background, it is supported by a Technical Board of nationally recognized experts in related disciplines. From this combination comes a text we feel is both practical and authoritative.

To show the general scope of the program it might be best to simply list the titles of the 12 Study Units:

- I      Cockpit Management
- II     The Nature of Command
- III    Pilot Traits
- IV     Pilot Error
- V      The Changing Cockpit Environment
- VI     Philosophies, Policies, Procedures  
         and Regulations
- VII    Judgement and Decision Making
- VIII   Management Style
- IX     Management Strategy
- X      Management Technique
- XI     Workload
- XII    Flight Deck Behavior

This Program utilizes the Multiple Learning Technique. This means that we let each pilot learn in the way he learns best. We consider each pilot as an individual and lean heavily on individualized instruction. We match each professional pilot participating in the program with a professional pilot on our staff especially trained in Cockpit Management and backed by our technical resources including our Technical Board.

The application of the Multiple Learning Technique takes the pilot through the following stages as he completes each Study Unit:

- 1.- An abstract
- 2.- A taped lecture
- 3.- The full text material
- 4.- Completion of a workbook
- 5.- Flash cards
- 6.- A post-test (self evaluation)
- 7.- Time is allowed for hands-on observation
- 8.- A taped panel discussion of the subject being studied by members of our Technical Board
- 9.- He responds to Interactive Discussion Questions (in writing or on tape cassette)
- 10.- A personal response from his Instructor/Consultant
- 11.- Hangar Flying publication (Interesting interaction among participating pilots and consultants)
- 12.- Telephone communication direct with his Instructor/Consultant if needed.

Finally, each participating pilot is invited to attend two Workshops for face-to-face discussions of each Study Unit with members of our Technical Board or staff.

We believe that this program presents the maximum opportunity to influence behavioral change. The program is spread out over approximately one year to permit the necessary time for proper depth of learning and to provide opportunity for hands-on observations of the course material in flight situations.

It is interesting to note that if the participating pilot should improve his personal performance by only 7/10ths of 1% during any ONE month of his remaining career, he would have justified the total cost of the program (B-727 equipment).

Of course, improved operational efficiency is not the only basis of program justification, it may be done equally well on the basis of flight safety or passenger service.

Recognizing that the needs of a particular company may differ from those of another, our basic script will be placed on a computer so that individual modifications can be made for each participating company. In this way they can take advantage of our basic research and development (thus saving much time and money) without finding conflict with their individual beliefs and policies.

Our Technical Board is just being formed. At this time we are most fortunate to have verbal agreements from:

Dr. Lee Bolman, Lecturer, Graduate School of Education,  
Harvard University

Captain Robert N. Buck, Trans World Airlines (ret.),  
Consultant, Writer

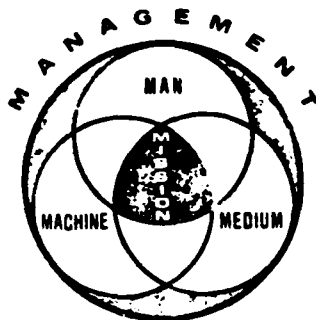
Dr. Robert Simpson, Director, Flight Transportation  
Laboratory, Massachusetts Institute  
of Technology

Captain Richard Stone, Delta Air Lines, ALPA Human  
Factors and Aeromedical Expert

Dr. John L. Sullivan, Professor of Sociology,  
Suffolk University

Those desiring further information, or wishing to comment on our approach to these problems, are cordially invited to contact:

Captain Bob Mudge, Director  
Cockpit Management Resources  
Post Office Box 969  
Center Harbor, NH 03226  
(Tel. 603-253-6063)



*Not Sent / Not Rec'd*  
*10/13*

**SYSTEM SAFETY, INC.**

7722 Bridle Path Lane  
McLean, Virginia 22102  
Telephone: (703) 356-5065

December 1, 1980

Mr. Walter Luffsey  
Associate Administrator  
Federal Aviation Administration  
800 Independence Avenue, S. W.  
Washington, D. C. 20591

Dear Walt:

This letter is forwarded pursuant to the view you and others expressed at the recent DOT/FAA Human Factors Workshop inviting comments in followup to the discussions in Cambridge.

First of all, however, please accept my sincere thanks for the invitation to attend the meeting. I found it extremely valuable personally in improving my knowledge of the pulse of human factors activity in civil aviation. Also I believe the FAA's posture of focusing attention on human error problems was enhanced greatly by the attendance of Mr. Bond and yourself, the excellent choice of speakers, and the overall professional conduct of the meeting including reasonable time for questions.

The comments offered below are in the form of suggestions or recommendations for consideration by your office based on what I heard. In some instances they are merely expansions of ideas I explored from the floor at TSC. I would, of course, be pleased to discuss them further with you or members of your staff at a time of mutual convenience. The comments are numbered for ready reference during any future communications.

1. Schedule further workshops which would encompass human factors problems in general aviation, the air traffic control system (especially as affecting controllers), maintenance activities and V/STOL operations (including helicopters).
2. Take steps to eliminate the drum-pointer altimeter from the system where IFR approaches can be expected. This could readily become a relatively long term program if the alleged reliability, cost and backfit problems in using a counter pointer instrument are really present. That, in itself, is a subject that probably really needs careful examination.

Mr. Walter Luffsey  
December 1, 1980  
Page Three

Also the enclosed "Human Factors in Accident Investigation" paper given in Europe last year indicates my continued interest for all of us to gain a better understanding of human factors problems and a much better "handle" on their solutions.

Accordingly, if I can be of service to the FAA in any training or indoctrination capacity, please do not hesitate to give me a call. I definitely plan to get back into the seminar business next year as exemplified by the most recent company brochure I had printed (also enclosed).

Once again, congratulations on a very meaningful meeting. Hang in there!

Sincerely,



C. O. Miller

COM:bf  
Enclosures

Mr. Walter Luffsey  
December 1, 1980  
Page Two

3. A comprehensive study should be undertaken to evaluate operational hazards in computer based systems such as INS, R/NAV, Flight Management and HUD installations. Included should be a requirement for a human error analysis of the basic design which should be tracked by recording and reporting of mistakes made during test and early operational use of the system. If, as one manufacturer's representative suggested during the meeting, this type of evaluation has been done on their system, the results should be disseminated.
4. In a general sense similar to (3), FAA should expand their required Failure Mode and Effects Analyses (FMEA's) to include human operator "failures" wherever such hazard analyses are required during the certification process. Indeed, consider abandoning the FMEA designation in favor of a Hazard Analysis concept to communicate a broader scope to the required effort.\*
5. Develop or otherwise encourage the preparation of a human factors investigation protocol to apply to accidents, incidents, or other events of possible accident prevention significance. Consider such information for inclusion in any Civil Aviation Human Factors Handbook that may be prepared using existent manuals as a starting point.
6. Indoctrinate FAA investigative personnel and key management officials in human factors technology including investigative techniques to be applied to human error events of possible accident prevention significance. (This would also seem to apply to some of the airline personnel as contrasted to the manufacturer's panel members.)

In connection with items (5) and (6), be advised I lectured a few hours to FAA personnel in early 1976 on the subject of human error as part of an ARINC Reliability and Maintainability training course. Whatever ultimately happened to that program is unknown to me at this time. Similarly, I lectured rather extensively on human error prevention through the Flight Safety Foundation as well as my own company after leaving NTSB in 1974 ... an activity that was suspended while I attended law school from 1977 until August of this year.

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\* See Miller, C.O., "Hazard Analysis and Identification in System Safety Engineering," 1968 Annals of the Assurance Sciences (New York: ASME, 1968), pp. 336-343, for further explanation of this concept. Copy enclosed.



Deanna S. Kitay Ph.D.

3126 Beluche Drive

Galveston, Texas 77551

November 28, 1980

Guice Tinsley  
Office of Aviation Safety  
800 Independence Avenue S.W.  
Washington, D.C. 20591

Dear Guice:

I most appreciated the invitation to participate in the recent DOT/FAA Human Factors Workshop on Aviation at the Transportation Systems Center, Cambridge, Mass.

As a follow-up and in view of my interest in human factors, I would like to respectfully submit the enclosed comments and suggestions toward the next workshop. Recognizing that this workshop was quickly assembled and was general in nature, I offer the following, also quickly assembled.

FORMAT:

1. billed as a workshop, the format did not encourage the participation of your distinguished audience. There were two main reasons for this:
  - a) the size of the group facing a panel generally serves to encourage only those who feel comfortable rising to a microphone
  - b) the knowledge that all responses were to be recorded for use in a NPRM was severely inhibitory to this group.
2. in the future, it may serve your objective more efficiently to reduce the size of the group and use a roundtable or several small discussions per subject. During a second day, for example, chairpersons or moderators, could join in a larger group discussion to reflect the consensus of their assigned discussion groups and then open THAT discussion to the floor.
3. to guarantee a generous productive exchange, no use of dialogue for NPRM's or other semi-judicial evidence.

OBJECTIVES:

1. if the objectives were obtain input from the representative groups, it is not apparent that this occurred to any great extent. I believe this was due to the above in FORMAT.
2. there were two specific references made with regard to objectives. HOW to achieve objectives was requested from Sig Poritzky, however few responses resulted. One notable exception arose from Dick Gabriel in the WHAT to achieve. He outlined 6 objectives:

Guice Tinsley  
November 28, 1980

- a) define performance criteria
- b) define performance standards
- c) design guidelines
- d) deal with the necessity for compromise
- e) deal with the necessity to establish priorities
- f) design programs useful for broad participation

Speaking as an individual participant, I would like to include the possibility of re-vitalizing CAMI as the center of study into which the various groups may contribute, not only in terms of ideas and data, but also in terms of discussion and conceptualization.

RESULTS USEFUL TOWARD THE NEXT WORKSHOP:

To this observer, several results from this initial effort were apparent:

1. representatives of various interest groups DO like to talk to each other.
2. there exists a surprising lack of understanding as to what human factors is, let alone how to apply it across broad heterogeneous interests. This was particularly evident in operator management where human factors is equated with vague psychological meaning and which may be found in 'charm school'. This observation ought to be the first issue to be dealt with in future workshops.
3. in industry, there is some quantification of those environmental and sensory stimuli effecting human performance decision processes, but there is also a reluctance to pursue a dialogue as to the utilization of this data to maximize human performance. This reluctance is a practical one due to :
  - a) fear of opening up costly uncertainties
  - b) unwillingness of industry human factor effort to assume responsibility in this area.

It may be useful to discuss human factors as an applied human engineering science whose data points help to maximize the 'fit' between flight deck instrumentation and human operator/manager of the information. It is important to recognize, among other things, that this would result, not in absolutes, but a sliding scale of tolerable performance. One of the finest statements came from Boeing, "... pilot decisions follow from mental imagery." This, in my view, is right on target and opens up a research direction which includes a range of human factor methodologies that could be made compatible with industry and labor and acceptable to the FAA.

4. At the risk of being redundant, I will just mention that the military ought to be included since some of the best research in this area is available from the Air Force ( fixed wing ) and Army ( Helicopters ).

From a brief review of my notes, I have sketched out a summary of the issues that emerged from this workshop and may serve you in planning for the future ( Table I ).

Guice Tinsley  
November 28, 1980

Finally, I have enclosed a rough draft of an article that I have worked on since the August Congressional hearings re: re-charter of the FAA. It is a rough draft that will be reduced for publication; however before I work further on it, I would most appreciate your comments and criticisms. The premise upon I based the paper is that the issues of air safety today reflect the history of aviation and further, the weakness of the legislative history of air safety may be found in the Federal Aviation Act of 1958. The safety issues of today are less a product of the current FAA or its Administrator, than they are of its history. I offer an alternative to legislative reorganization the recognition of a national air safety transportation policy.

I appreciate the volume of work ahead following the recent workshop, but if you could return the enclosed manuscript to me with 10 days in the prepaid postage envelope I would most appreciate it. I will also request that this manuscript not be circulated.

Thank you again, Guice, for your interest and I look forward to speaking with you soon again. I can be reached either at my home office, 713-744-4741 or through my Washington office as per my card.

Best Regards,

*Deanna S. Kitay*  
Deanna S. Kitay, Ph.D.

TABLE I

## WORKSHOP #1 - general inquiry

Administrative	Human Factor Subject Matter	Government's Role
<ol style="list-style-type: none"> <li>1. what is human factors?</li> <li>2. what is the range of experimental methods in use? what are their limitations? what are their potential?</li> <li>3. review of the terminology in human factors. how may it be improved to be useful across heterogeneous groups?</li> <li>4. review of concepts of 'reliability' and 'validity' as applied to research data</li> <li>5. review of terms such as criteria, standards, minimums</li> </ol>	<ol style="list-style-type: none"> <li>1. Workload definition and measurement               <ol style="list-style-type: none"> <li>a) pilot: helicopter and fixed wing</li> <li>b) controller</li> </ol> </li> <li>2. Workload issues               <ol style="list-style-type: none"> <li>a) comparative vs absolutes numbers</li> <li>b) optimum vs range</li> <li>c) difference between tolerable and acceptable</li> </ol> </li> <li>3. pilot decision making processes               <ol style="list-style-type: none"> <li>a) mental imagery and strategy</li> </ol> </li> <li>4. information processing</li> <li>5. flight deck management</li> <li>6. crew function and safety               <ol style="list-style-type: none"> <li>a) relation of crew size to function</li> </ol> </li> <li>7. evolution of cockpit responsibility and job               <ol style="list-style-type: none"> <li>a) from controller of events to a manager of information</li> </ol> </li> <li>8. Relationship of fatigue to               <ol style="list-style-type: none"> <li>a) workload</li> <li>b) flight deck management</li> <li>c) antecedent conditions</li> <li>d) expected performance</li> </ol> </li> <li>9. Forecasting performance</li> <li>10. upgrading accident investigation to include human factors</li> </ol>	<ol style="list-style-type: none"> <li>1. Data Base               <ol style="list-style-type: none"> <li>a) extent</li> <li>b) access</li> </ol> </li> <li>2. economic models to evaluate costs/benefits to human factors to design technology</li> <li>3. models to yield acceptable priorities where compromise is required</li> <li>4. coordinating mechanisms for continued participation between labor, industry and government</li> </ol>

# Human factors in air safety

By Deanna S. Kitay\*

**C**REW size in the commercial air carrier has been a cause of dispute for nearly 15 years. The US Air Line Pilots' Association (Alpa) and member groups of the International Federation of Air Line Pilots' Associations (Ifalpa), have maintained the view that the addition of a third crewmember provides additional surveillance required by an increasingly complex air traffic environment, and is necessary to meet an operational workload not otherwise met with two crewmembers. Underlying that argument is the assumption that increasing air traffic complexities and advancing technology in the new and proposed cockpit configurations will result in a dangerous cognitive workload increase.

Opposing the pilot's position are industry and management views that safety standards set by present crew complement regulations are adequate and that there are no data which suggest that the regulations are inadequate. They maintain that compliance with procedures is evidence of crew proficiency and, therefore, an acceptable workload, and believe that labour's interest is in securing jobs, not safety. The final argument is that advanced cockpit displays and procedures, which include computerised flight-management systems, serve to reduce workload.

The point around which the dispute continues is the lack of operational evidence showing the measurable effects of additional crewmembers upon crew performance. Such effects should permit prediction of operational effectiveness, and enhance the certainty of crew proficiency. If the effect of an additional crewmember was exactly measurable, it would be possible to compare the effectiveness of an additional crewmember with that of an added computer flight management system.

Is there any evidence apart from opposing labour and industry/management viewpoints to support a hypothesis that crew size is a useful or meaningful factor related to safety? Is the primary function of a crew defined by an interdependence between crew performance (human factors) and cockpit requirements, or an intra-dependence between crewmembers which secondarily may influence an interdependent function? In either case, the relevance of crew size to function needs to be determined before a valid safety argument

favouring two or three can be recognised. As with other circumstances where multiple variables affect the outcome, including multiple value judgements, the results of such studies may be expected to be less than absolute.

There are at least four independent sources of evidence to support the view that crew size may be a meaningful criterion of aviation safety. They are: statistical evidence obtained from pilot error accidents; National Transportation Safety Board (NTSB) recommendations concerning lack of cockpit crew co-ordination; the Federal Aviation Administration aircrew performance enhancement and error-reduction (APEER) study; and empirical evidence obtained from Air Force studies of crew size.

## Pilot Error

Aviation safety statistics indicate that, while aviation accidents have declined as a proportion of flying activity in the last quarter century, the percentage of pilot error accidents has remained nearly constant. The "constancy" of that observation could reflect a statistically induced constancy arising from the pre-established code of 82 possible pilot error cause factors available to the NTSB; the limited judgement or human factor experience of accident analysts; or a fundamental and constant incompatibility between the demand of the systems and human ability.

Following the United Airlines DC-8 accident at Portland, Oregon, in 1978, the NTSB recommended to the FAA that all air carrier operators indoctrinate flight crews in principles of flightdeck resource management, with particular emphasis on the merits of participative management for captains and assertiveness training for the cockpit crewmembers. According to the NTSB, lack of cockpit crew co-ordination was shown to be a factor in four accidents and two incidents over the last six years. The Safety Board stated that crew co-operation failed because either the flight crew fixated on a problem at hand and thereby failed to monitor the flight properly, or the copilot did not adequately communicate with, or receive communications from, the captain. The Safety Board believes that the recurring problem of poor crew co-ordination results from a breakdown in cockpit management and teamwork at times when the responsibility for safety must be divided among all members of the flight crew. The recommendation by the NTSB to the FAA in 1979 to provide principles of flightdeck resource management to air carrier operations may serve to point out a

recurring problem, but it also raises a question of larger interest. During the last decade, the National Aeronautics and Space Administration (Nasa), at its Ames research facility, has been and is actively involved, through its Manned-Vehicle System Research division, in problems of flightdeck management. One programme's specific objectives were to:

1. Determine system/pilot communication requirements (especially CRT displays) for aircraft flight management in the 1980s;
2. Evaluate the pilot's ability to be constantly informed of past, present and (predicted) future system status;
3. Evaluate the pilot's ability to monitor the system for deviations beyond acceptable tolerances, or system failures; and
4. Evaluate the pilot's ability to make decisions and execute them in an accurate and timely manner.

The Safety Board recommends remedial action to the FAA following an accident investigation, but it does not have the authority to enforce. The above example of the availability of Federally-funded safety-related research information indicates long-standing awareness and concern about crew performance and flightdeck performance, but a lack of co-ordination of safety-related research information.

In August 1977, the APEER programme was announced by the FAA. Its purpose was to minimise the occurrence, and consequences of, human error in the cockpit. The multi-million dollar budget for the period 1977-79 was allocated for the following reasons: the high incidence of pilot error accidents; the project's potential for safety improvements; the increasing complexity of aircraft systems; and the increasing complexity of flight procedures.

Cockpit and operational procedures, and cockpit displays and controls, were cited as major objectives for study. Procedures that contribute to cockpit problems appear to result from ATC communications during approach, ATC restriction to intermediate holds, radar vectoring and pilot disorientation, and cumulative workload as a result of concurrent procedures. The study determined that cockpit displays and controls require additional human-factor data, such as the basic components that form such a system, information transfer techniques and human capability with various systems.

One objective in the problem area of cockpit and operational procedures was "to make use of the third cockpit crewmember in aircraft where this person is available through revised cockpit procedures." The latter half of this statement "... where this

\*The author is assistant professor of neurosurgery at the University of Texas Medical Branch and holds a pilot's licence with an instrument rating. She has been involved in the field of aviation human factors research for a number of years. The article is based on a paper presented to the Netherlands Air Line Pilots Association.

person is available through revised cockpit procedures," may very well be the only exemplary explanation of the political status of crew complement. The FAA contends there is a need to make use of a third cockpit crewmember because "... this crewmember is not fully utilised as an integrated part of the crew." The "need" is a result of the FAA's contention that the availability of that person is determined by pilot airline negotiations. The third crewmember is thereby pre-judged by the FAA as not having probable safety value, and is given political status.

Although the APER programme is designed to evaluate crew role in cockpit procedures and cockpit design, crew size is held to be a cockpit procedure and thus negotiated accordingly.

The FAA position that this "political issue between pilots and airlines... cannot be resolved technically until improved workload assessment techniques become available" begs the issue. A significant portion of the APER budget is directed at workload assessment. It is appropriate to expect that, considering APER's objective to evaluate crew role, crew size and operational workload would be an empirical inquiry before the fact.

One example of crew size and workload evaluation was conducted by the Crew Equipment and Human Factor Division, Aeronautical Systems Division, Wright Patterson Air Force Base in 1976. A series of flight tests was conducted to assess a three-man versus a four-man crew on a KC-135 aircraft, equipped with a dual inertial navigation system. The purpose of the study was to evaluate the feasibility of a reduced crew during a variety of air-refuelling operations. Crew workload performance was assessed according to the formula:

$$\text{Percentage crew workload} = \frac{\text{time required} \times 100}{\text{time available}}$$

"Only after the relationships between crew size and function have been established can the number of crew be properly assessed"

This formula gave the average unit to accomplish a task. Depending on the type of mission or circumstance, copilot workload was found to vary from 117 per cent for a minor mission change to 145 per cent for a major change involving a complex procedure or a failure of the navigational system. To compensate for increased workload, the authors observe, critical tasks were omitted, the concept of "see and be seen" failed, and attention was concentrated on system operations rather than flying the aircraft. Working faster to handle task overload was an acceptable solution providing the effort was of short duration—up to 30 minutes—and that the task overload was in the order of 20 to 25 per cent. The results of a three-man crew on a KC-135 for refuelling operations indicated that the addition of navigational duties to the copilot's task resulted in an excessively high workload on the copilot that jeopardised the mission and constituted a safety hazard. Checklist items omitted on various flights bear a striking similarity to NTSB criteria of pilot error:

- Did not have time to do most of occasional hydraulic, electrical, fuel, oxygen and engine checks usually done at level-offs every 20 to 30 min
- Did not look outside during air-borne-radar-directed approach
- Missed a radio pre-flight check
- Missed two altimeter checks during penetration
- Missed fuel log, level-off checks and radio logs during various segments of the flight
- Forgot heading checks in grid
- Missed several entries in communication log
- Omitted radio calls
- Omitted other take-off checklist items

For the pilot, the checklist items omitted were:

- Called for engine-start check but did not wait
- Missed several entries in communication log

The overall objective of the Air Force study was to determine minimum crew requirement in order to reduce operational costs and still meet mission safety. Under the mission studied, the inertial navigational system increased the probability of poor crew performance in a three-man (in contrast to a four-man crew) and acted primarily to increase workload resulting in the omission of cockpit procedures. The additional crewmember was observed to overcome all the unacceptable disadvantages encountered in the three-man crew. The copilot's workload was reduced to reasonable levels, no critical checklist items were omitted and the concept of "see and avoid" was preserved.

The number of experiments are few, but several points may be isolated for further evaluation of crew complement. The same workload formula, applied to different crew complements, resulted in measurable and varying changes in workload associated with similar changes in cockpit performance of procedures. This suggests that safety should be evaluated in terms of mission, where this determines the human factor requirements for minimum crew size. For example, advanced cockpit displays and automated flight-management information may be less important determinants of crew size than differences in mission requirements, where crew action and co-ordination is a factor of greater significance than cockpit display. It is reasonable to consider operational differences between long, medium and short-haul aircraft would support the hypothesis that minimum crew size is mission-specific.

The above independent data suggest that the efficacy of crew function is both an interdependent function between crew and operational requirements, as well as an intra-dependent function reflecting group dynamics, training resource management and other factors. It is reasonable, therefore, to suggest that crew performance is a valid safety-related human factor. But crew size may not be an absolute standard, and will vary according to circumstances.

How do we account for the fact that a labour industry dispute continues at the same time that inter-governmental safety-research authorities show evidence of safety information around the very point upon which the dispute is centred? This observation suggests a larger problem of which crew size is only a symptom. The prolonged dispute about the efficacy of crew size concerns the process of safety decisions rather than the decision makers. What are safety decisions? Who and what makes safety decisions? The complexity of the decision resides in the understanding of the term safety. The problem is illustrated by the recent European...



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held in September 1979 (*Flight*, December 22, 1979, page 2046).

More than 600 pilots and flight engineers from 18 flightcrew associations in Western Europe and the United States called for a required three-man crew with a side-facing flight engineer station on all future transport aircraft. Capt Frits Brouwer, chairman of the Europilote Council meeting, stated: "We want, for the safest possible operation, a three-man integrated cockpit in which human technology is applied to the maximum extent. Airline managements have not taken into account the point of view of the men who have to operate the equipment. We must tell management that we will not fly the aircraft unless it is acceptable to us." Capt Brouwer rests his argument on an assumed superiority of a three-man crew based on yet-to-be-applied human factor technology. It is an assumed superiority because there is no applied ergonomic or human factor evidence which demonstrates a functional relationship between crew size and flight operations. What does exist is a vast human factor literature and technology to which organised pilot groups have contributed in workshops, seminars and task force efforts. Ergonomics or human factor information is best described as scientific observation of behavioral and physiological factors associated with isolated examples of human performance. Except for limited work in simulators, these observations do not necessarily impart useful pilot performance information in highly complex and often variable aviation environments. The availability of human factor or ergonomic data in published research, which is unrelated to crew function or pilot performance, is not evidence of correlation.

The threat of an international pilot strike to force a safety decision shows a disregard for the potential value of available data (to which, it is important to emphasise, pilots have contributed), and it defeats future credibility of human factor input and helps to perpetuate political resolution of safety issues. On the other hand, is it the responsibility of organised pilot groups to prove the usefulness of human factors to air-safety decision makers? Who is responsible? The answers to these questions are parts of the problem of which crew size is only a symptom.

A labour strike on behalf of assumed superior safety standards may not only be practical, since success could result in a change in those safety standards, but judicious in the resultant increase in members of that labour force, much to the chagrin of critics.

An accident is an unexpected event. Assessing the probability of an event or an unexpected event is an essential step in accident prevention. The process of determining this probability is an inherent part of

safety decision analysis, which includes not only assessing the probability of events, but also assessing their consequences. A safety decision incorporates at least two factors: the probability of accident type and severity, and an evaluation of the acceptability of that assessment.

In calculating the probability of an unfavourable outcome, examples of multiple and interactive factors are:

- Accident statistics
- Subjective evaluation
- Empirical observations in the simulator or laboratory or field conditions
- Flight-testing
- Human factor technology
- Economic investment—training, design, manufacture
- Influence of economic events upon the aircraft industry
- New evidence.

Subjective values and empirical information can be combined to produce a quantified index of probability or certainty of risk or hazard. Risk or hazard may be evaluated from four basic lines of investigation: who or what is at risk; what are the adverse consequences; how is risk/hazard related to adverse consequences; and what is the overall risk?

An essential factor in an estimate of risk/hazard is its acceptability. A low probability risk/hazard, but with serious consequences, may be less acceptable than a high probability of risk/hazard but with minimal consequence. Thus safety may be defined as the judgement of the acceptability of risk or hazard.

### Personal limitations

But this definition is limited when factors preceding an unfavourable outcome are variable, unknown or uncontrollable. Performance may vary between poor and excellent on individual occasions. Variability of human performance reflects personal limitations which combine with circumstances in a linear or exponential manner. This is the area of human factors study. The critical questions are: what are the determinants of human performance; what is the expectation of minimum-error performance, and what is the functional relationship between performance and mission requirements? If mission requirements depend upon superior performance, then what is the limit of variability in performance consistent with minimum error? Variable performance, from poor to excellent, may not be important to the final outcome for one definition of successful mission, but may be critical to another. On the other hand, reliability of operation may be highly dependent upon performance of limited scope requiring the expectation of a narrow margin of human error. Once limits are set, the operative question then is, to what extent is mission requirement dependent upon a given level of performance? This introduces rela-

bility to the safety definition.

Redundancy is engineered into product design not only to provide reserve, but to be sure against the loss of function in dependent systems. This is most evident in aircraft flight systems and least evident in flight crews. Industry and manufacturers support the view that human redundancy is made unnecessary by advancing cockpit technology. On the other hand, pilot groups contend that the final decision in flightdeck operations, particularly in times of abnormal or emergency conditions, resides with the crew and the provision for human operator redundancy. Management occupies a middle position by supporting the view that mere compliance with procedures demonstrates performance proficiency. Training to procedure proficiency is considered acceptable as meeting safety standards. Safety and economics are not completely independent factors. Economically efficient flight operations are naturally demanded by airline management.

In turn, industry is stimulated to make a more economic product to meet pressures such as spiralling fuel costs. For example, the US Air Transport Association, in its 1979 year-end statistics, reports that, since 1973, airlines have increased fuel-use efficiency by 43 per cent, but fuel costs have risen 66 per cent. In that same period, fuel costs rose 18 percentage points of total operating costs, while load factors rose only 11 per cent. The International Air Transport Association forecasts that average worldwide fuel prices for the fourth quarter of 1980 will be 93.3 per cent higher than the same period last year. These economic factors are forcing airline management to re-evaluate the economics of current aircraft types in their attempts to maximise profits and cope with fuel-cost pressures expected throughout the rest of the century.

The criteria by which decision-makers balance the merits of economic survival and the probability of potentially hazardous events lead to the ultimate definition of safety standards: a judgement of the acceptability of risk/hazard, consistent with maximum reliability, and compatible with costs.

It is generally accepted that safety is a relative attribute. The popular view is revealed in the question, "how safe is safe?" and the even more popular answer, "as safe as you want it to be." Although these simple statements seem like common sense they do not make complex safety issues simple or help to resolve conflicting views. Crew size has been presented here as a long-standing, complex issue which first requires agreement that it is a valid safety-related factor. Only after the relationships between crew size and crew function have been established can the number of crew be properly assessed. □





**aerospace sector committee**

December 3, 1980

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Subject: Input to FAA Aviation Human Factors Research Program

Dear Mr. Luffsey:

The Aircraft Operations Subsector of the ANMC Aerospace Sector Committee would like to express concern over the human factors impact of the international adoption of a metric version of ICAO Annex 5, Units of Measurement to be Used in Air-Ground Communications. The Subsector, which represents the views of a number of aerospace industry organizations (see enclosed list), proposes the following points for your consideration in connection with FAA's aviation human factors research program, and requests that these views be included in the record of the November 24-25 workshop:

1. ICAO Annex 5 conversion goals are premature as they apply to the deletion of the three controversial units of measure widely utilized in the international airspace system, i.e., the vertical foot, bar, and nautical mile and knot.
2. We are concerned with the derogation of safety associated with deletion of the knot, nautical mile and foot, all of which have been used as international standards for years in approximately 85 percent of the free world. No in-depth study has been made in such critical areas as the human factors problems associated with pilot/controller interface, the undetermined costs of conversion, and the enormous problems associated with various alternative methods of conversion and transition periods.
3. We fully support the U. S. position of requiring extensive in-depth studies to resolve these and other associated safety issues to ensure that conversion can be accomplished safely and cost effectively so that the advantages of such conversion outweigh the disadvantages. It is most appropriate that the FAA, as the focal point for determination of the formal U. S. position, should take the lead in this effort to provide a reliable baseline of information from which to

Mr. Walter S. Luffsey  
December 3, 1980  
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plan. Additionally, the U. S. delegates to the ICAO Vertical Measurement, Bar and Nautical Mile Study Panels should be provided this valuable input on a timely and continuing basis.

It is therefore our strong recommendation, as a representative organization of aerospace industry users, to encourage the FAA to study the operational, safety and cost issues associated with metric conversion of the international airspace system. Attached you will find, in outline form, our perception of some of the critical areas requiring attention.

We further see the necessity of continuing coordination with industry to ensure consideration of their views. The ASC will be pleased to provide any assistance possible to aid in coordination with industry users, and our representatives would be glad to meet with you and your staff to discuss these recommendations further.

Respectfully,

*Barbara Boykin*

*for*

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Chairman, Air Operations Subsector  
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Encl. (2)

cc: A. P. Albrecht, Associate Administrator  
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IMPACT OF METRIC UNITS ON AIR OPERATIONS: AREAS FOR STUDY

I Human Factors

- A. Pilot cockpit workload and navigation procedures
- B. Controller workload and procedures
- C. Pilot-controller interface
- D. Dual presentations
- E. Conversion charts or procedures
- F. Pilot training
- G. Controller training
- H. Simulator (conversion of)
- I. Electronic and environmental readouts

II Transition

- A. Alternative methods and techniques
  - 1. Dual instrumentation
  - 2. One side of cockpit at a time
  - 3. Instruments (digital where possible, with self-contained capability of conversion from customary to SI)
  - 4. Scheduling of aircraft and crews over specific segments or city pairs
  - 5. Integrated computer conversion of instruments
  - 6. Conversion tables
  - 7. Soft vs. hard conversion
  - 8. Training period - recency of experience prior to conversion
  - 9. International coordination - procedures in the mixed environments
- B. Timing alternatives
  - 1. Short duration
  - 2. Gradual long range conversion
  - 3. Deadline date

III Cost Factors

- A. Airborne flight instruments and avionics
- B. Training
  - 1. Course material
    - a. films, slides
    - b. manuals
    - c. training aids
  - 2. Conversion of simulators
  - 3. Instructor training
- C. Charts, maps
- D. Conversion of DME (and other appropriate Navaids)
- E. Test equipment
- F. Retrofitting of existing aircraft

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